Linac to IP Simulations with QMUL High-Throughput Cluster

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- Aims
- Fast Feedback Systems at TESLA
- Multi-bunch simulations for TESLA
- Future plans

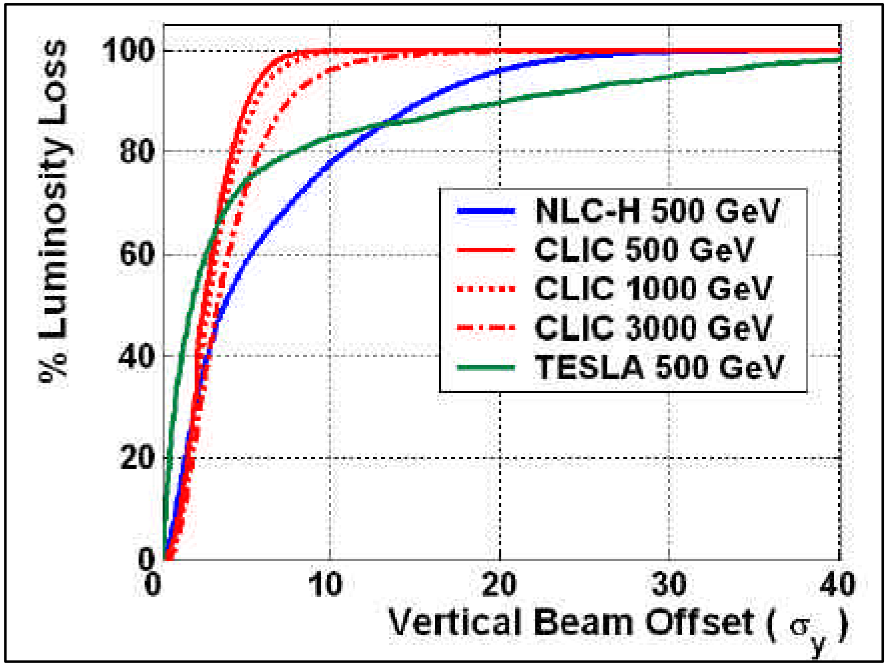
Aims

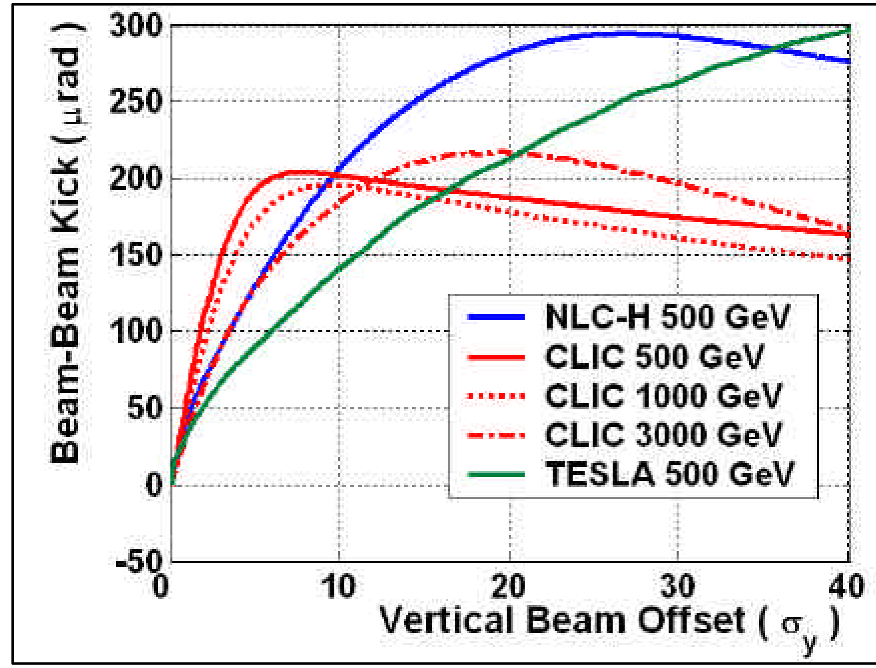
- Study performance of accelerators with multi-bunch tracking Linac-IP.
- Integrated test environment- all technologies/ all simulation environments.
- Provide database of IP parameters resulting from simulations for Particle/Accelerator Physics community (Lumi,Backgrounds etc).

Performance of TESLA with Angle + IP Fast Feedback

- Examine luminosity performance of TESLA 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.

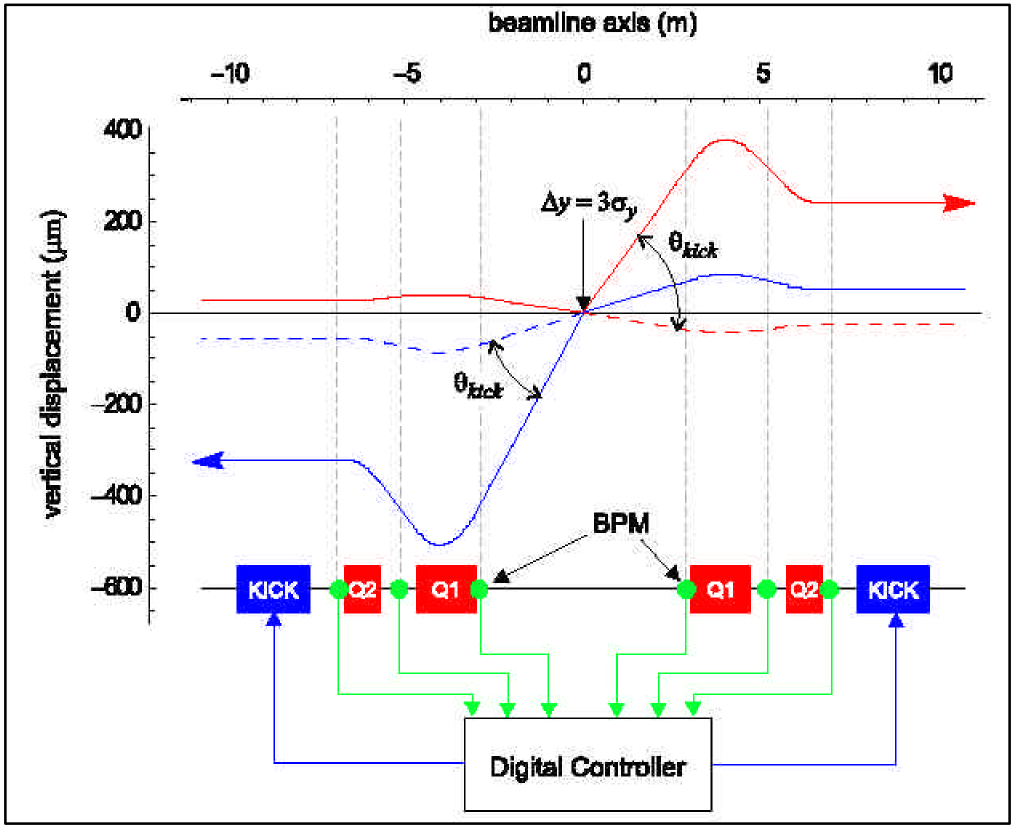
Beam-Beam Interaction





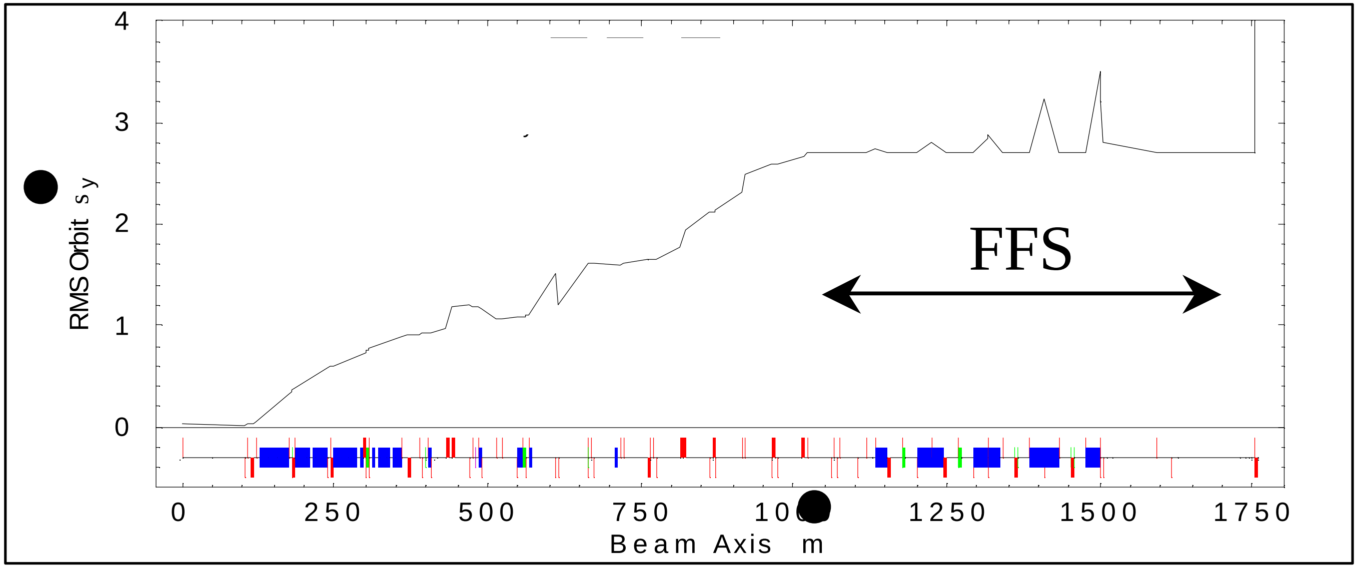
- Beam-beam EM interactions at IP provide detectable FB signal.
- Beam-beam interactions modelled with GUINEA-PIG or CAIN.
- Kick angle and percentage luminosity loss for different vertical beam offsets shown.

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



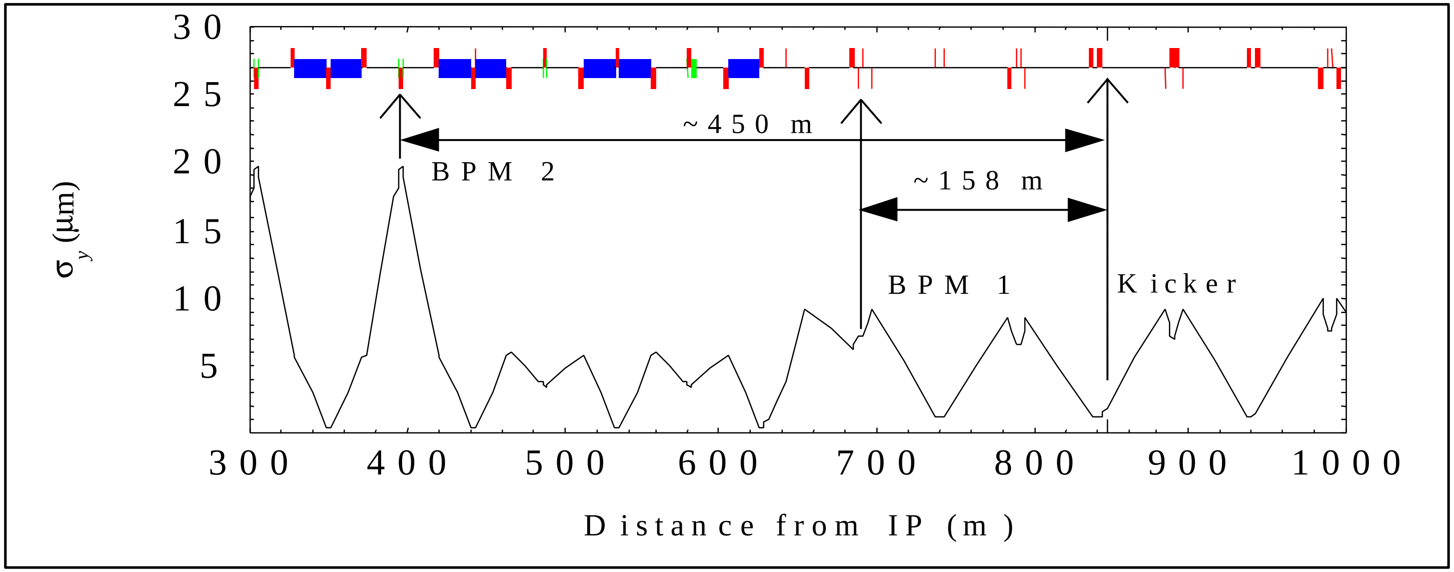
•Normalised RMS vertical orbit in TESLA BDS due to 70nm RMS quadrupole vibrations.

•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

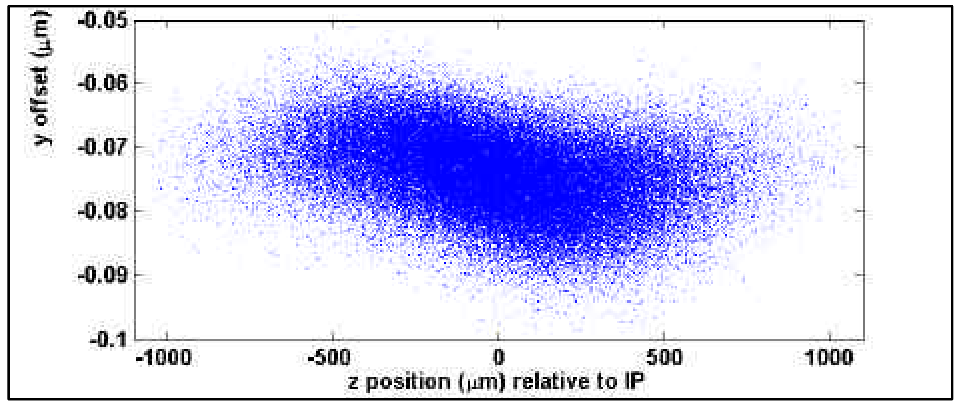


- **Place kicker at point with relatively high b function and at IP phase.**
- **Can correct ~130 mrad at IP (>10 $s_{y'}$) with 3x1m kickers.**
- **BPM at phase 90^0 downstream from kicker.**
- **To cancel angular offset at IP to 0.1 $s_{y'}$ level:**
    - **BPM 1 : required resolution ~ 0.7mm, FB latency ~ 4 bunches.**
    - **BPM 2 : required resolution ~ 2mm, FB latency ~ 10 bunches.**

Banana Bunches

•Short-range wakefields acting back on bunches cause systematic shape distortions:

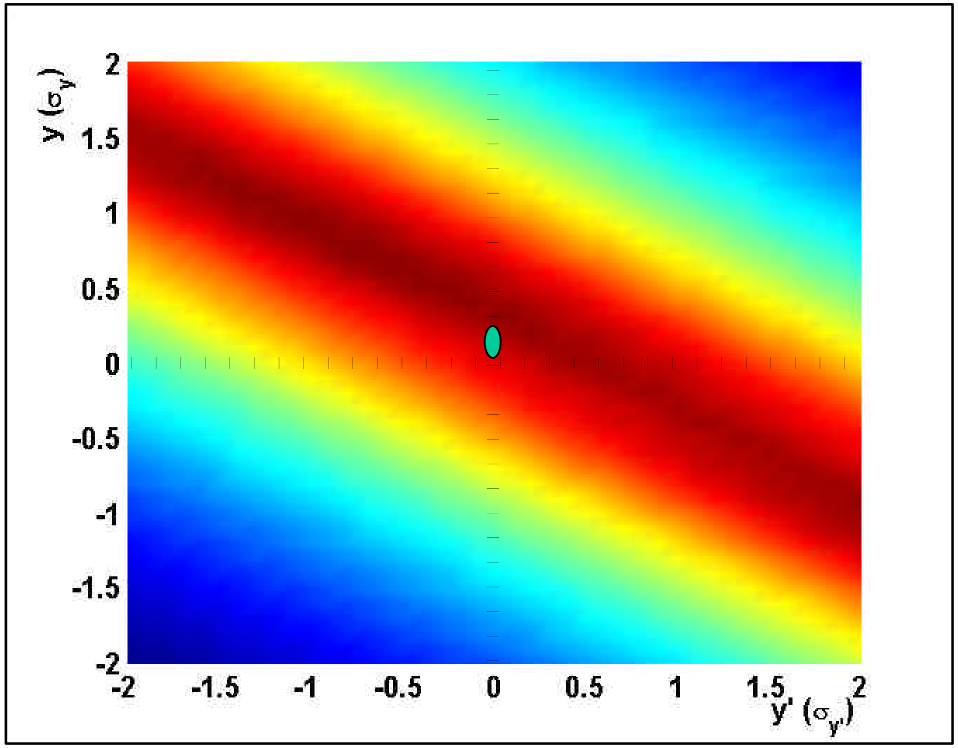
•Z-Y plane of a sample bunch:



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

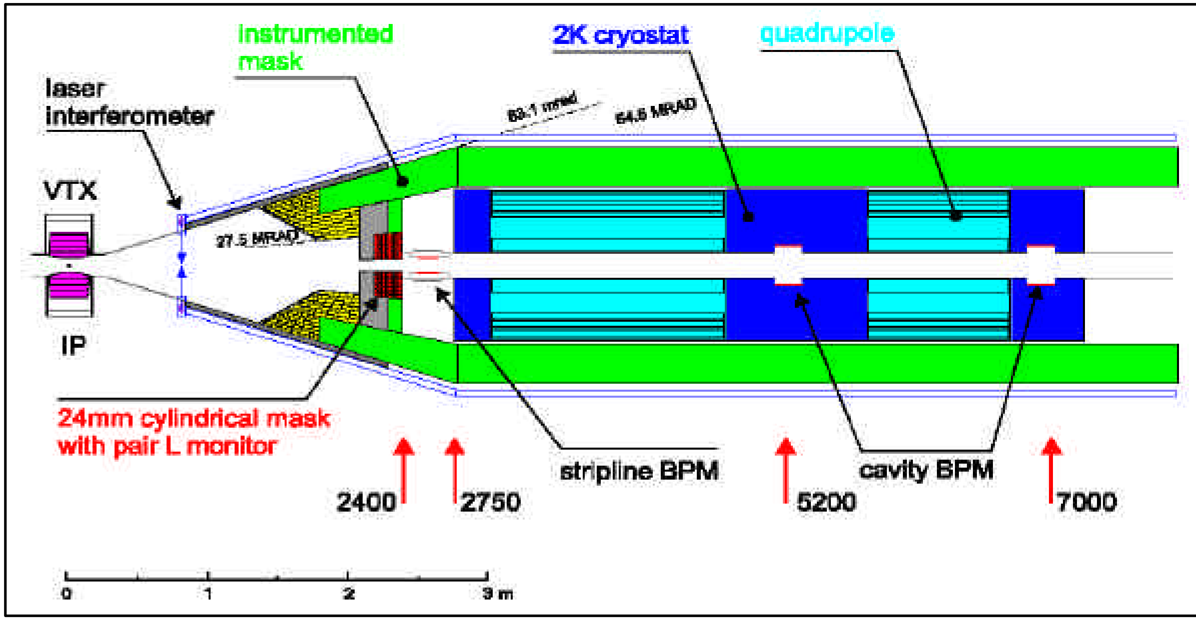
•Change in beam-beam dynamics from gaussian bunches.

Banana Bunch Dynamics

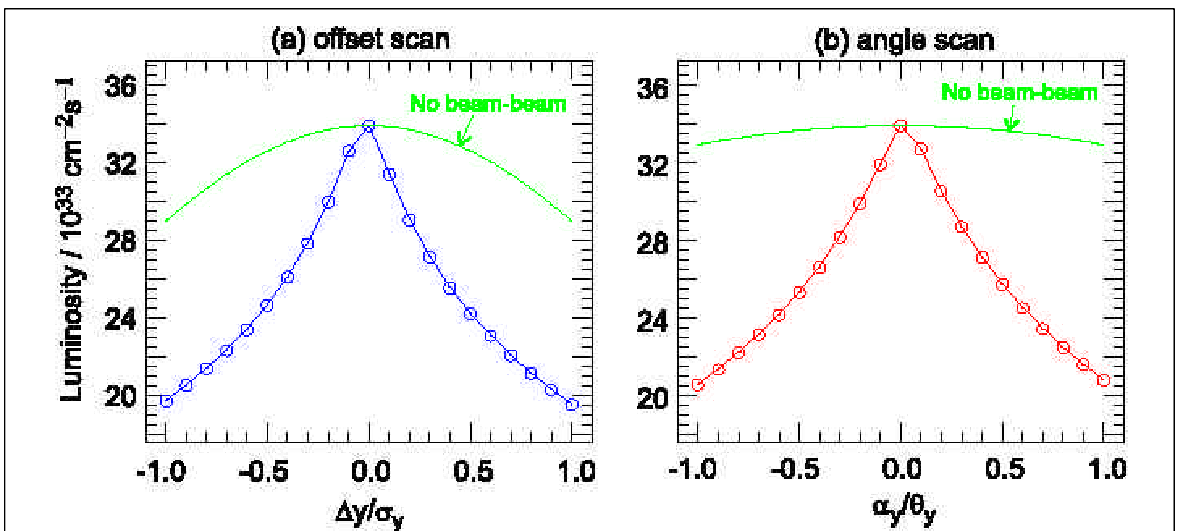


- Luminosity of a sample bunch over range of position and angle offsets.
- Wait for IP and ANG FB systems to 'zero' – then fine tune by stepping in y then y' using LUMI monitor to find optimum collision conditions.

Luminosity Feedback



TESLA IR



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

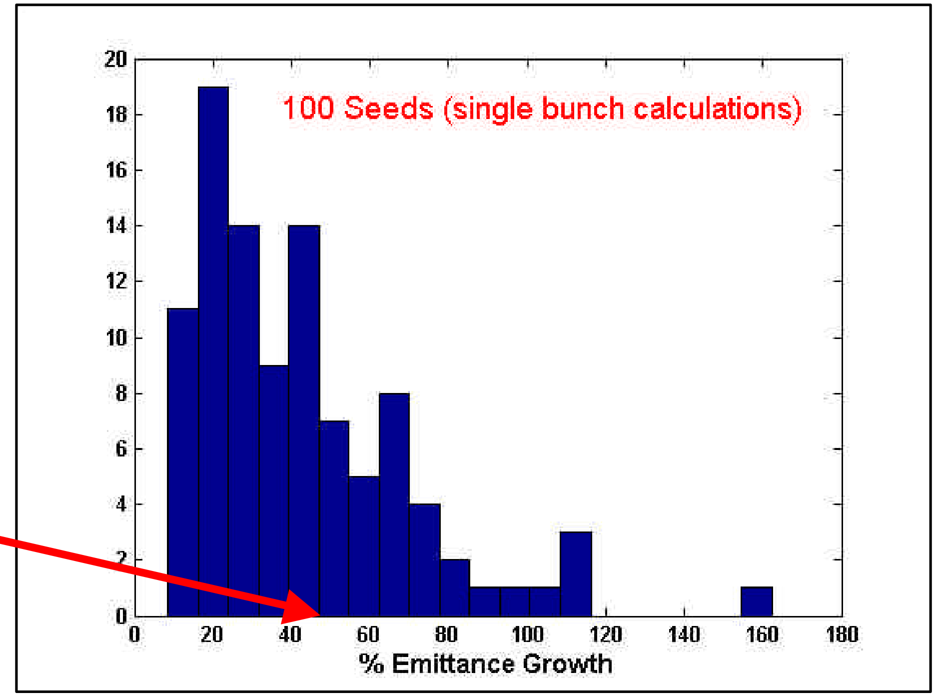
•QMUL Test GRID cluster- http://194.36.10.1/cluster

•Boxes run Redhat 9 Linux – have 100 Unix Matlab licenses.

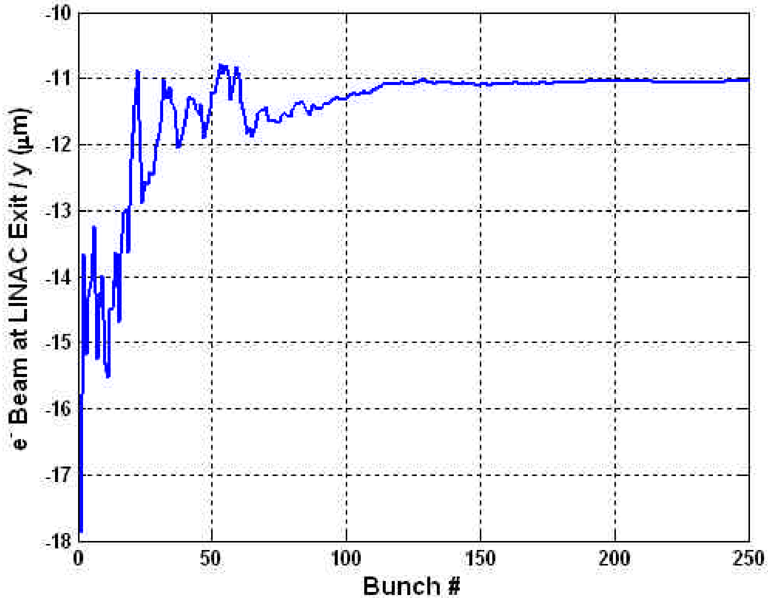
Linac Simulation

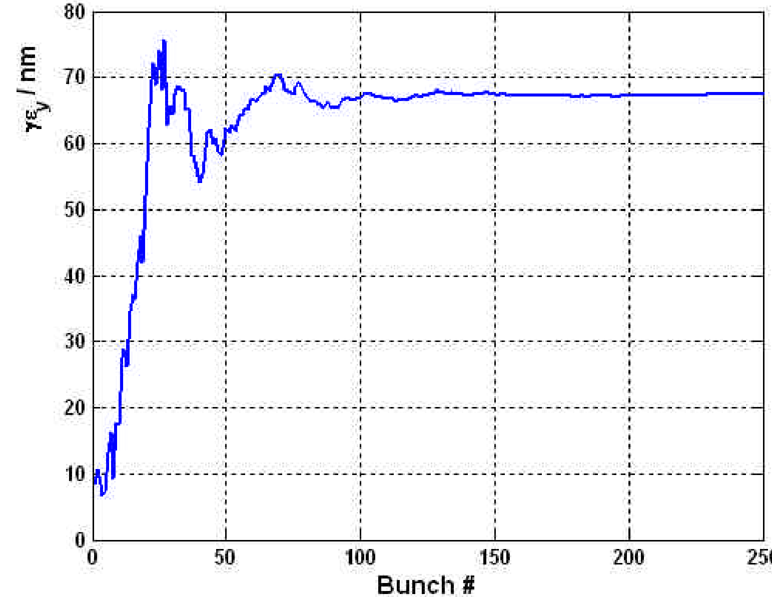
PLACET:

- **Structure Misalignment:**
  0.5mm RMS y, 0.3mrad y' error.
- **BPM misalignment: 25mm (y).**
- **Apply 1-1 steering algorithm.**
- **Choose lattice that gives approx.**
  50% vertical emittance growth.
  (single bunch tracking).
- **Injection: 0.2,0.5,1.0 s RMS error.**
- **Misalign Quads 100nm RMS in y.**
- **Detune structures.**
- **Generate 500 bunches**
  (multiple random seeds).



PLACET Output





- Electron beam at LINAC exit
  - y (left), emittance (right).
- Long-range wakes have strong effect on bunch train.
- Need to perform steering on <u>plateux</u> 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.**

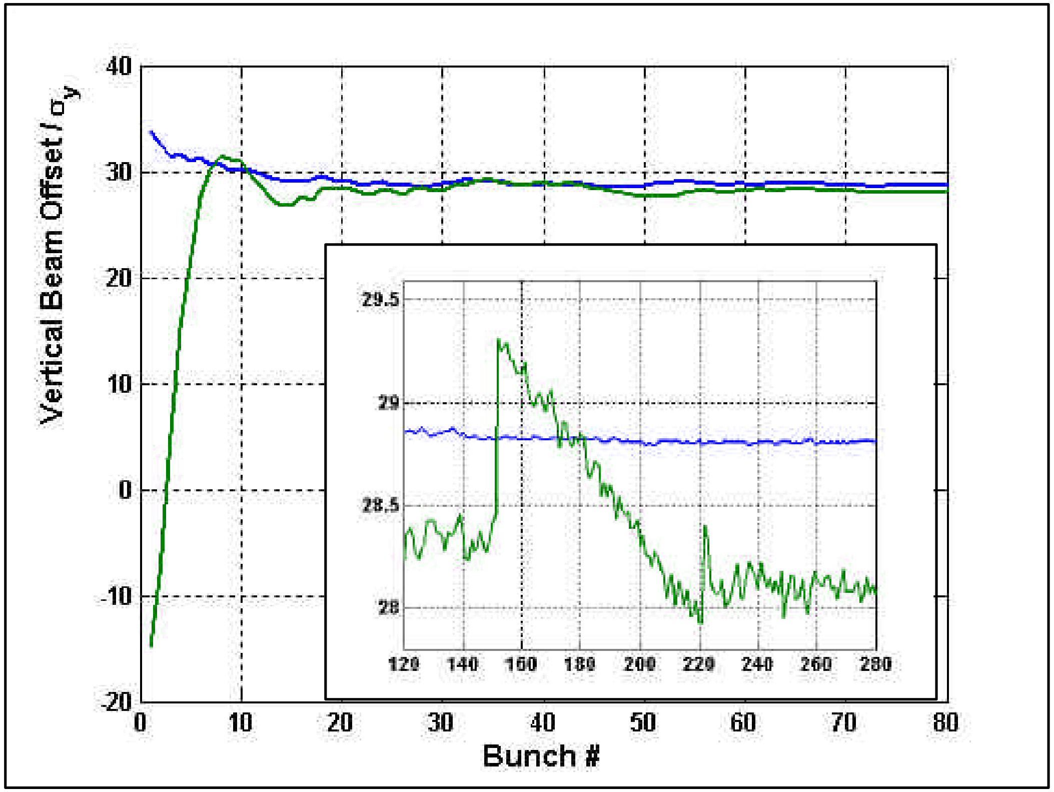
•Feedback (Simulink model in Matlab):

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

•IP (Guinea-Pig):

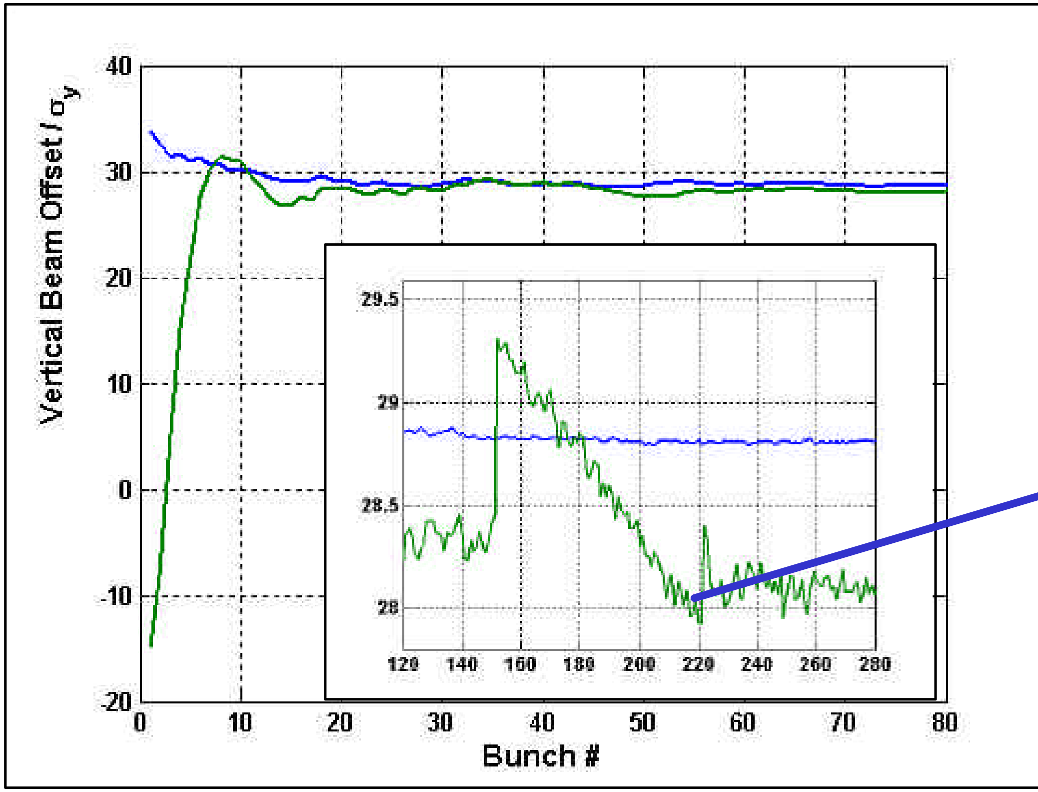
- **•Input macro-beam from MatMerlin BDS (non-gaussian).**
- **•Calculates Lumi & Beam-Beam kick.**
- **•Produces e^+e^- pairs -> track through solenoid field and count number hitting LCAL first layer for Lumi FB signal.**

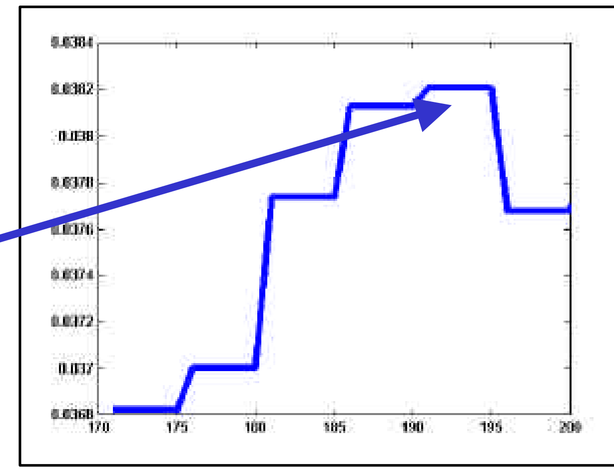
IP Feedback



- Corrects < 10 bunches.
- Corrects to finite Dy due to banana bunch effect.
- Vertical Beam-Beam scan @ bunch 150.

IP Feedback





5 Bunch e^+e^- Int. Signal

- Corrects < 10 bunches.
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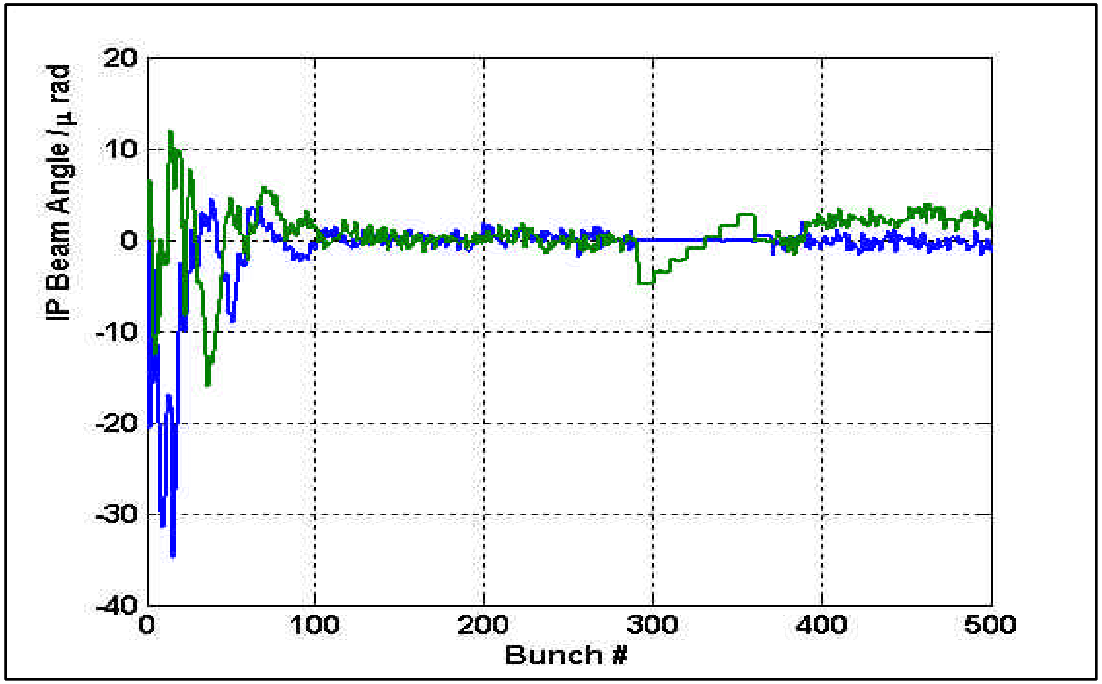
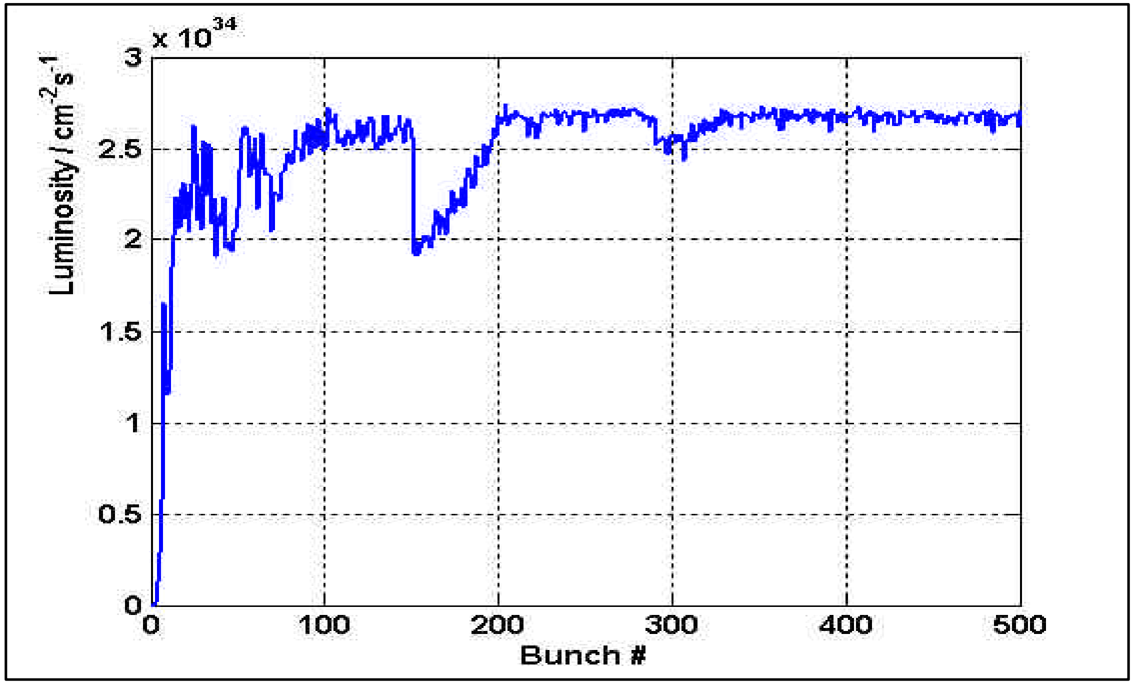
- Vertical Beam-Beam scan @ bunch 150.

Angle Feedback



- Angle scan after 250 bunches when position scan complete.
- Noisy for first ~100 bunches (HOM's).
- FB corrects to <0.1 $\sigma_{y'}$

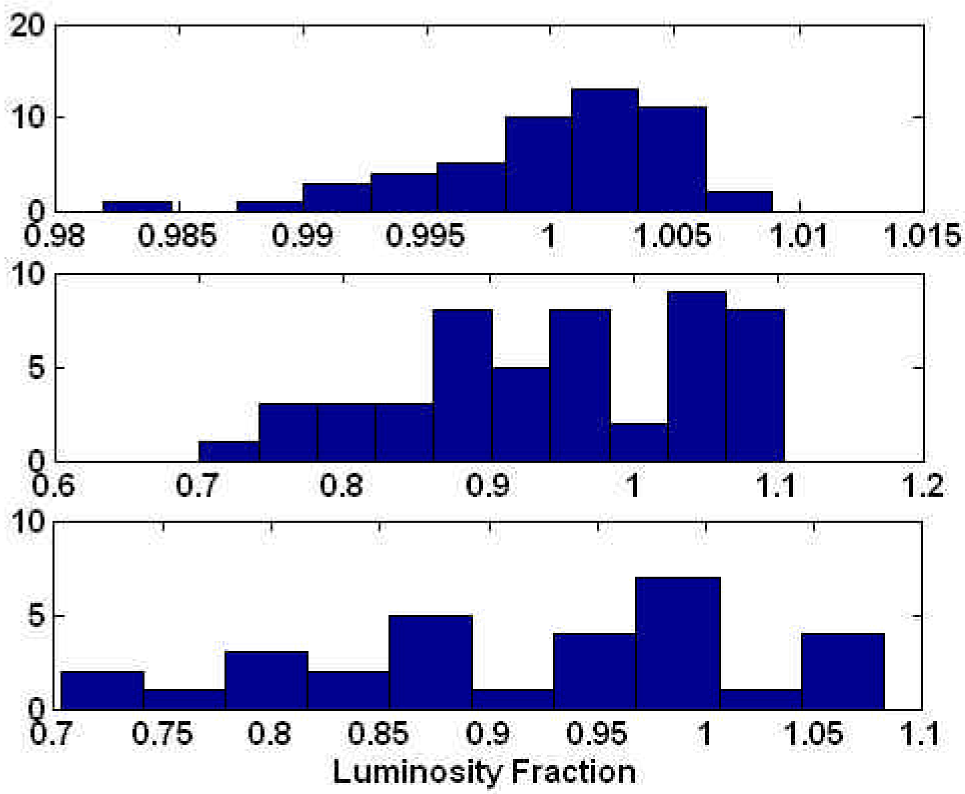
Luminosity



•Luminosity through bunch train showing effects of position/angle scans (small).

•Total luminosity estimate: L(1-500) + L(450-500)*(2820-500)

Multiple Seed Run (No HOMs)



No GM

m = 1.0 ± 0.005

GM (35nm BDS, 100nm Linac)

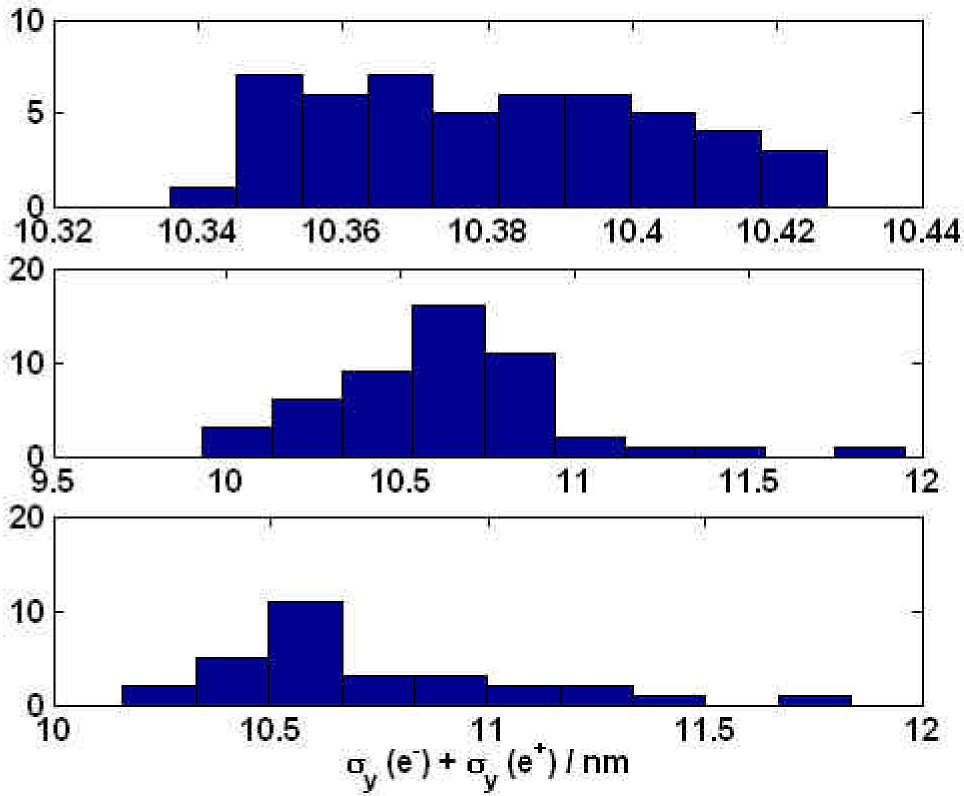
m = 0.95 ± 0.1

GM + 0.2s Inj. Jit

m = 0.92 ± 0.1

- **Luminosity fraction compared with mean no-Ground Motion case.**

Multiple Seed Run



No GM

m = 10.4 ± 0.02

GM (35nm BDS, 100nm Linac)

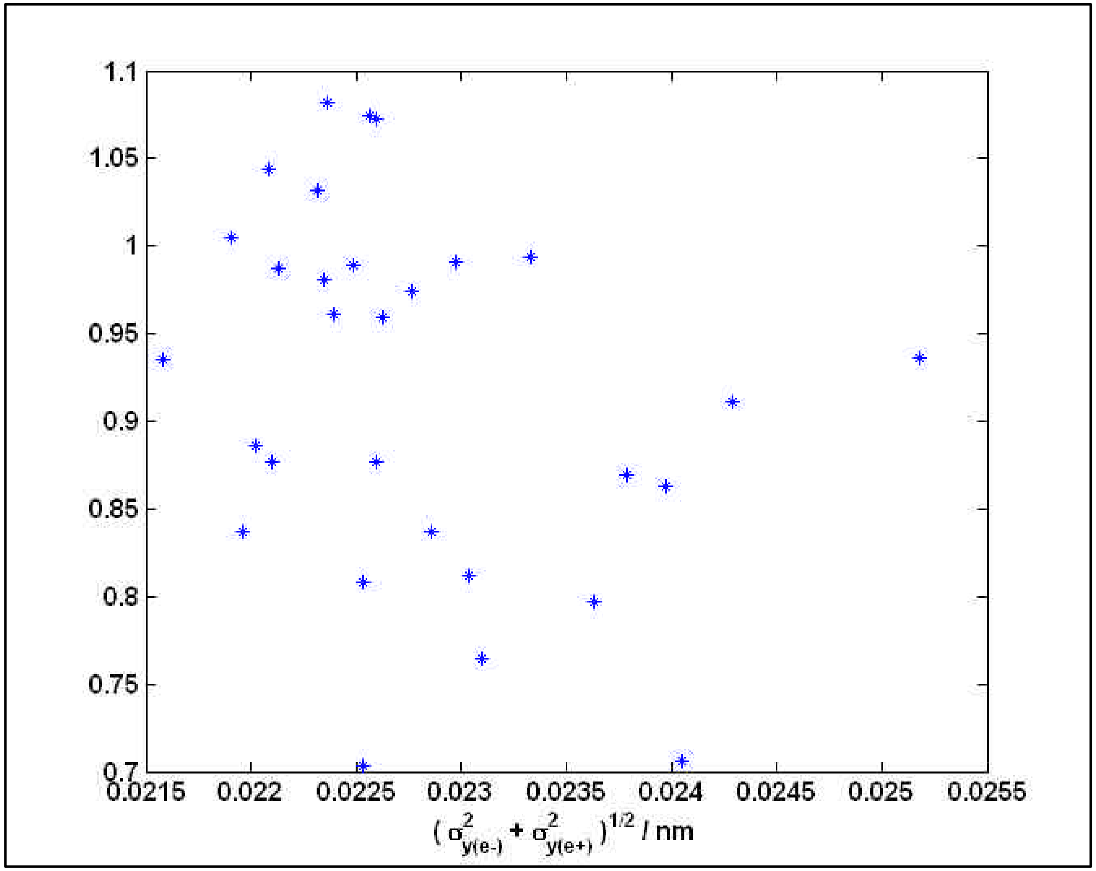
m = 10.6 ± 0.3

GM + 0.2 s Inj. Jit

m = 10.7 ± 0.4

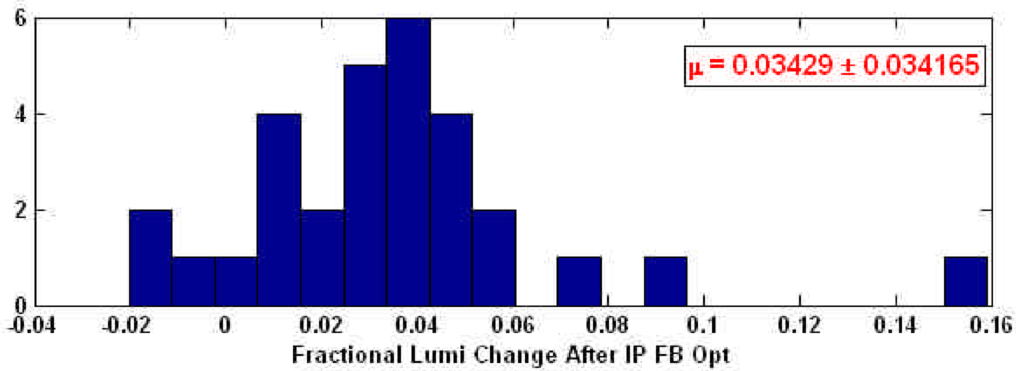
- **Sum of Vertical IP Bunch Spot Sizes.**

Extent of Banana Effect?

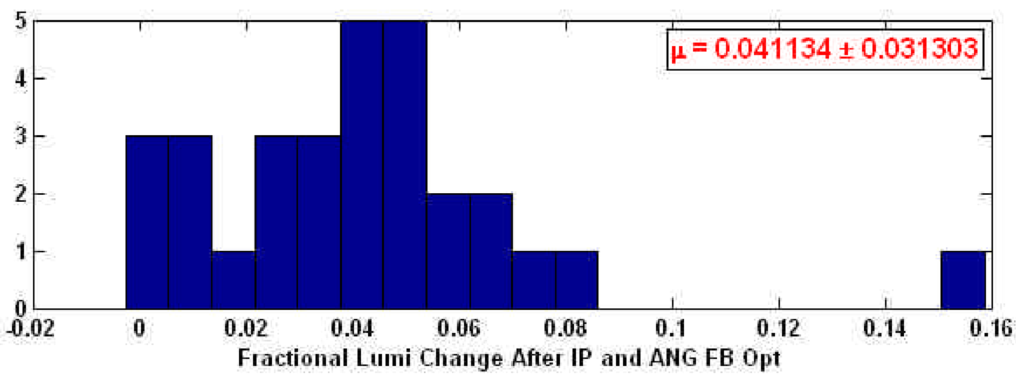


- Lumi proportional to 1/x if no banana (and offset), or optimised banana.
- No correlation -> lumi loss effects due to bunch shapes?

Effect of Lumi-Scan



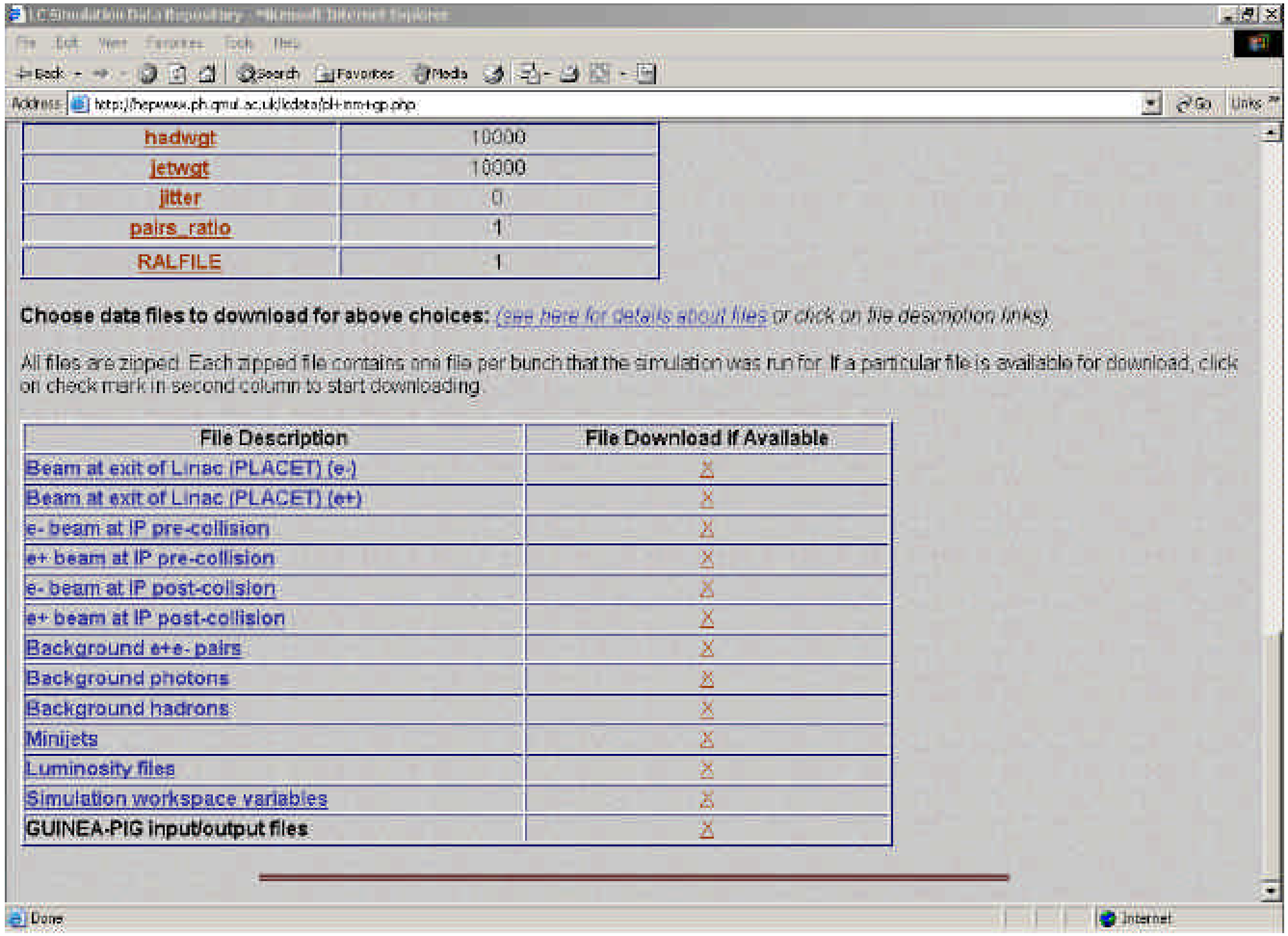
- After position scan



- After position and angle scan

- Effect of Pos & Ang Lumi scans compared with start of pulse with FB only.
- GM + 0.2 s RMS Injection error data.

LC Simulation Web Page



hadwgt	10000
jetwgt	10000
jitter	0
pairs_ratio	1
RALFILE	1

Choose data files to download for above choices: *(see here for details about files or click on file description links)*

All files are zipped. Each zipped file contains one file per bunch that the simulation was run for. If a particular file is available for download, click on check mark in second column to start downloading.

File Description	File Download If Available
Beam at exit of Linac (PLACET) (e-)	X
Beam at exit of Linac (PLACET) (e+)	X
e- beam at IP pre-collision	X
e+ beam at IP pre-collision	X
e- beam at IP post-collision	X
e+ beam at IP post-collision	X
Background e+e- pairs	X
Background photons	X
Background hadrons	X
Minijets	X
Luminosity files	X
Simulation workspace variables	X
GUINEA-PIG input/output files	X

- 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.
  - Incorporate other feedbacks in linac and BDS.
  - Crab cavity angle FB.
  - New BDS lattice(s).
  - Collimator Wakes.
- Similar tests with NLC (&CLIC)…
- New people at QMUL to work on simulations:
  - Tony Hartin (Phys. Programmer).
  - Shah Hussain (PhD Student).