Linac to IP Simulations with QMUL High-Throughput Cluster

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- Aims
- Multi-bunch simulations for TESLA
- Future plans

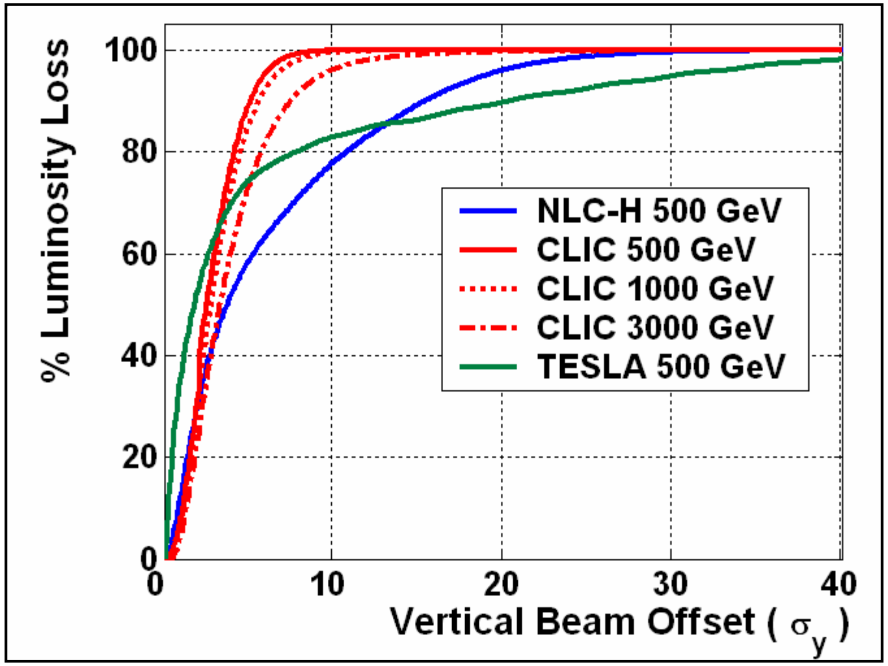
Aims

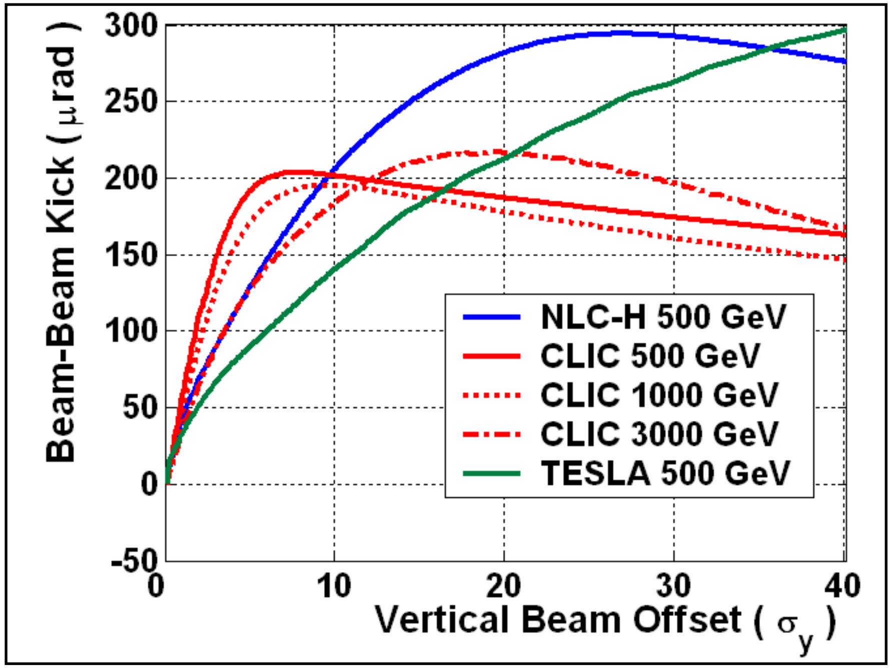
- Study performance of accelerators with multi-bunch tracking Linac-IP.
- Integrated test environment- all technologies/ all simulation environments.
- Provide database of IP parameters resulting from simulations for Particle/Accelerator Physics community (Lumi,Backgrounds etc).

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.**

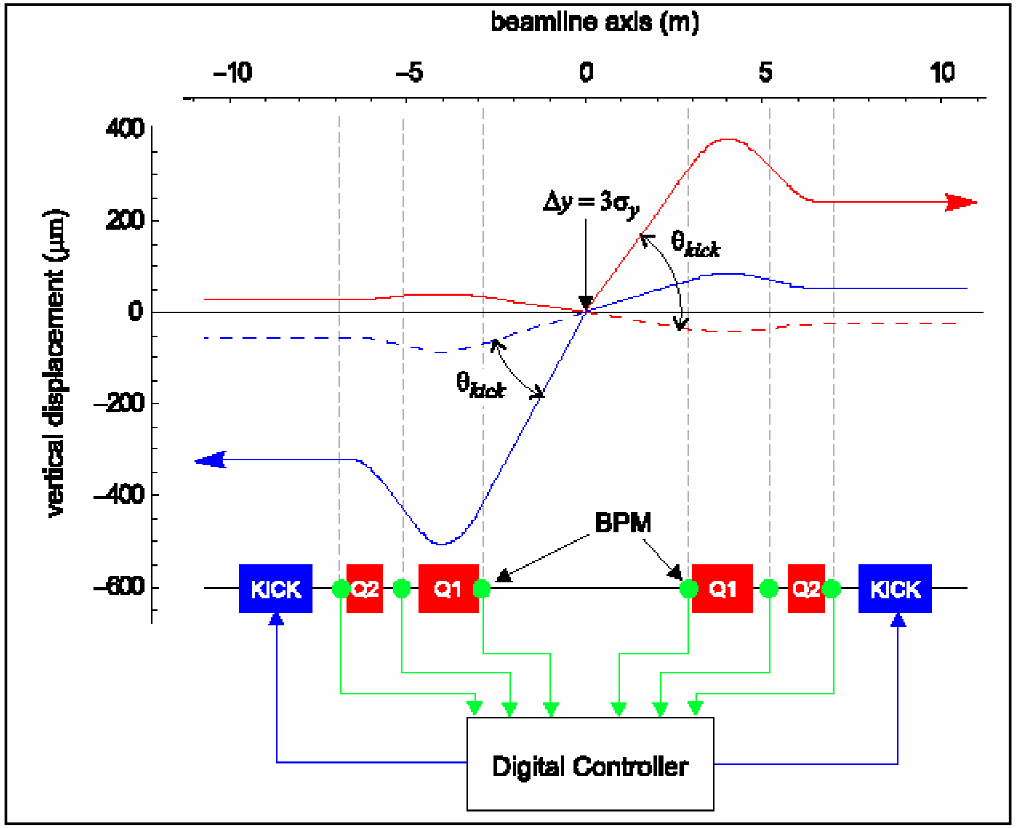
Beam-Beam Interaction





- 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

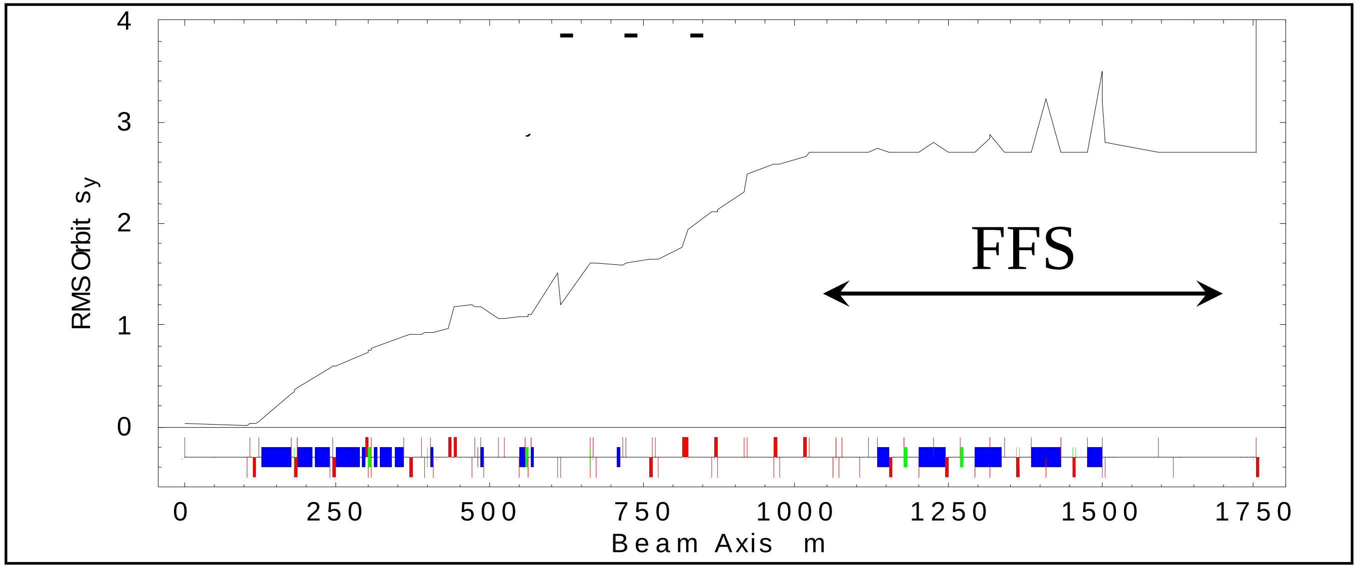


•Detect beam-beam kick with BPM(s) 1 or either side of IP.

•Feed signal through digital feedback controller to fast strip-line kickers either side of IP.

TESLA Fast Feedback Systems:

Angle Feedback

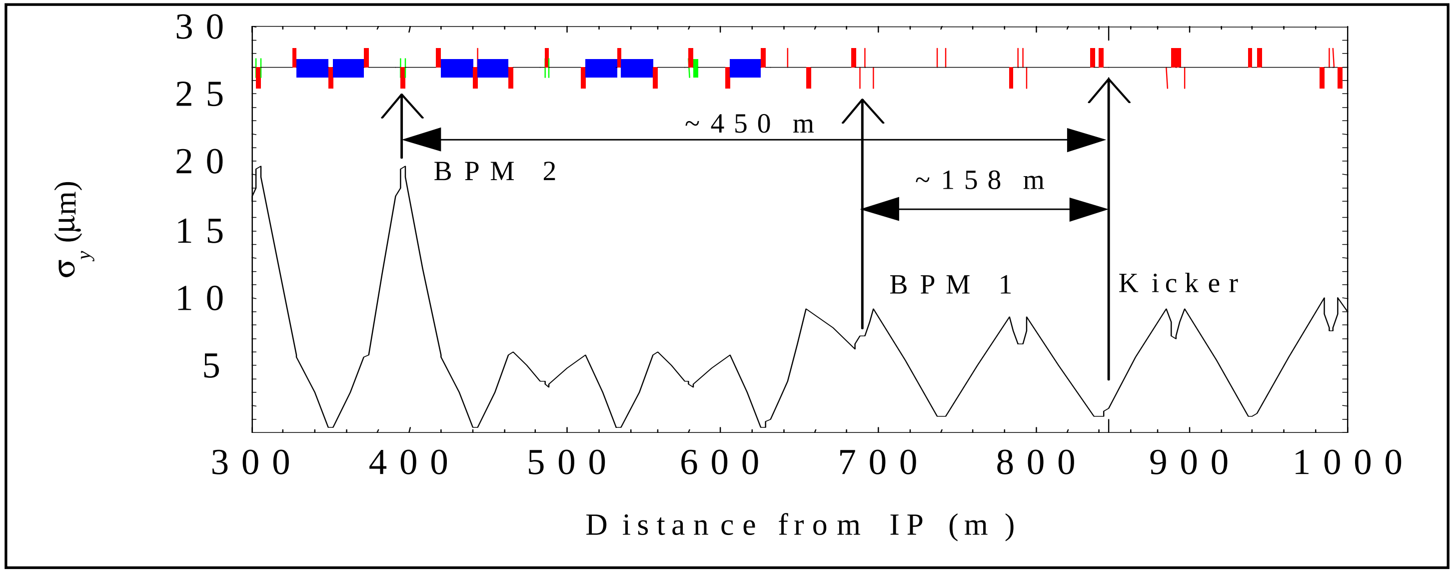


•Normalised RMS vertical orbit in TESLA BDS due to 70nm RMS quadrupole vibrations.

•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

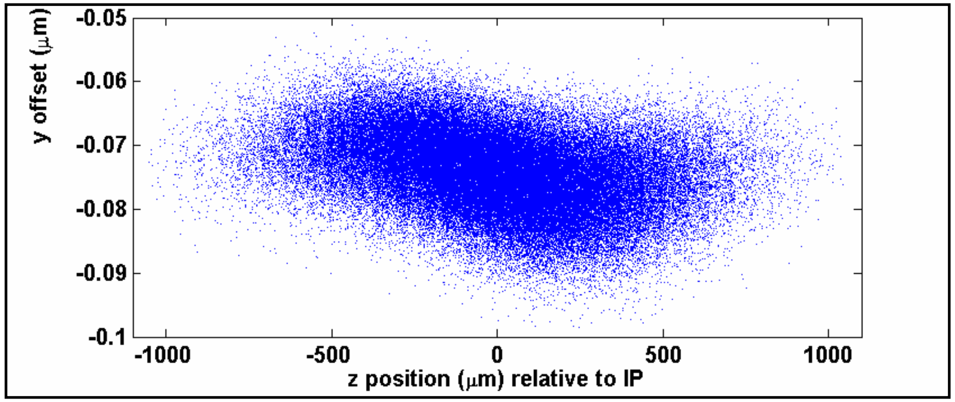


- Place kicker at point with relatively high β function and at IP phase.
- Can correct ~130 µrad at IP (>10$\sigma_{y'}$) with 3x1m kickers.
- BPM at phase 90^0 downstream from kicker.
- To cancel angular offset at IP to 0.1$\sigma_{y'}$ level:
  - BPM 1 : required resolution ~ 0.7µm, FB latency ~ 4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

Banana Bunches

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

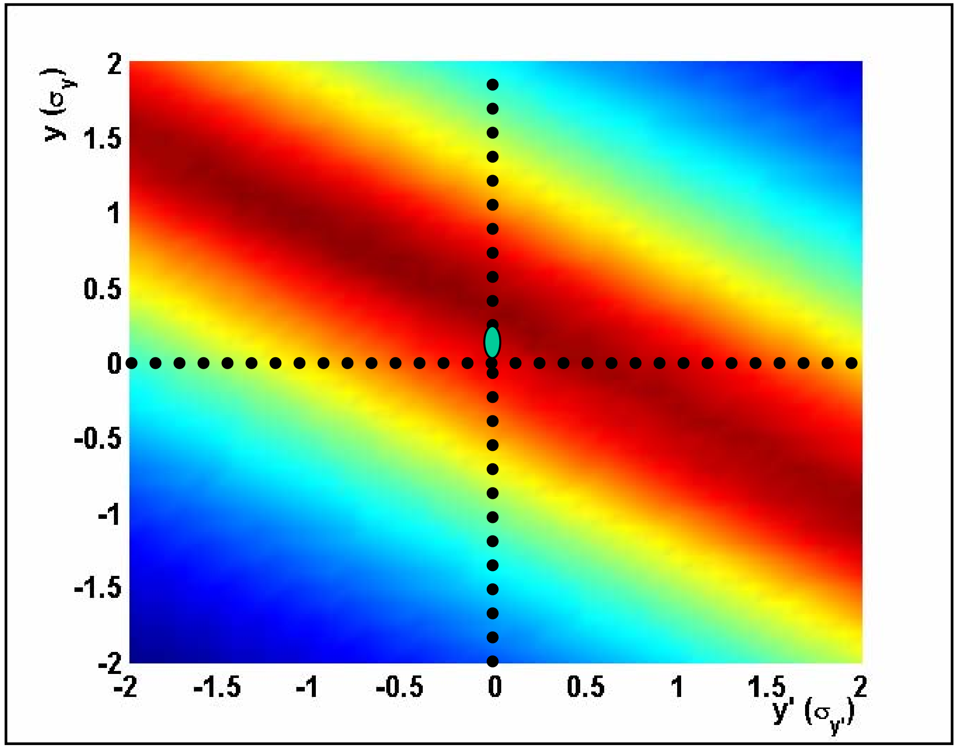
- •Z-Y plane of a sample bunch:



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

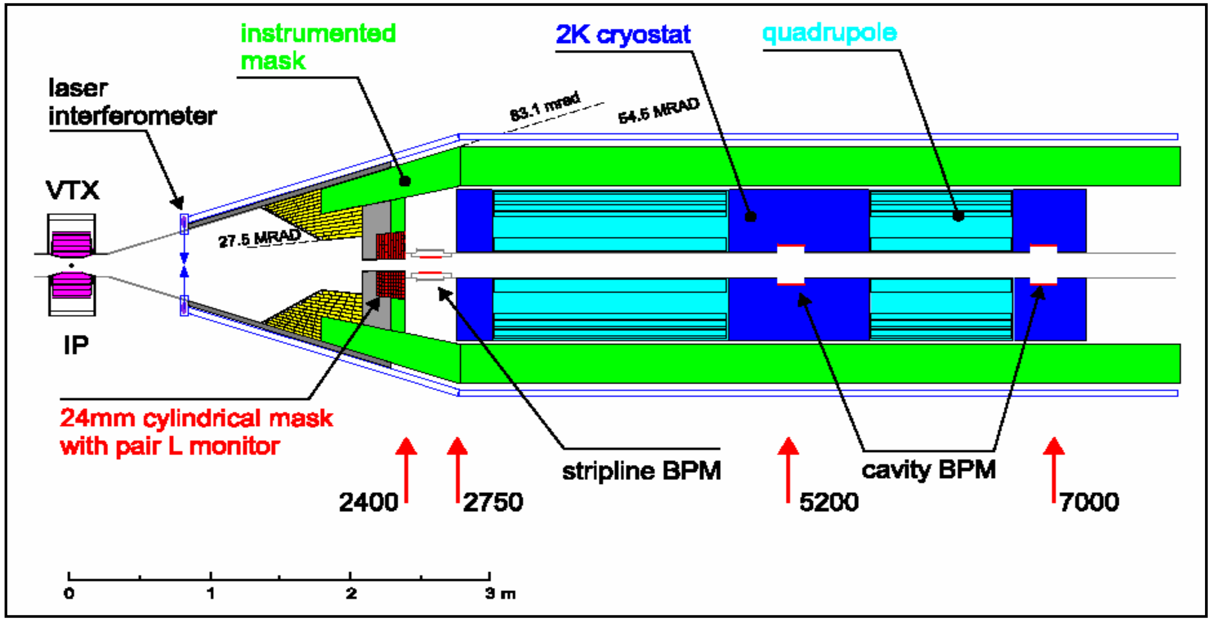
•Change in beam-beam dynamics from gaussian bunches.

Banana Bunch Dynamics

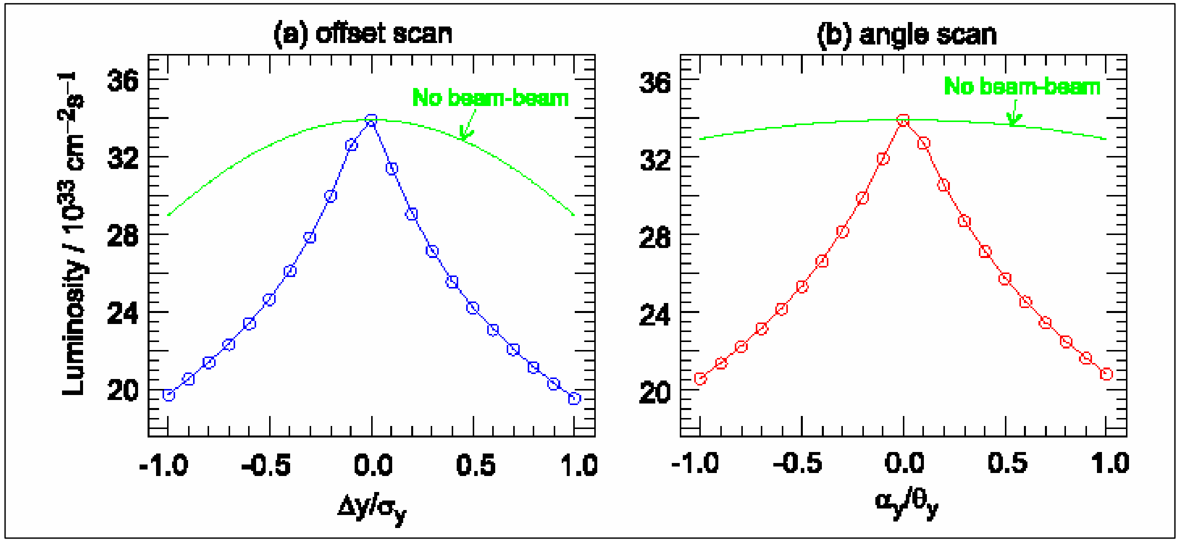


- Luminosity of a sample bunch over range of position and angle offsets.
- Wait for IP and ANG FB systems to ‘zero’ – then fine tune by stepping in y then y’ using LUMI monitor to find optimum collision conditions.

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.

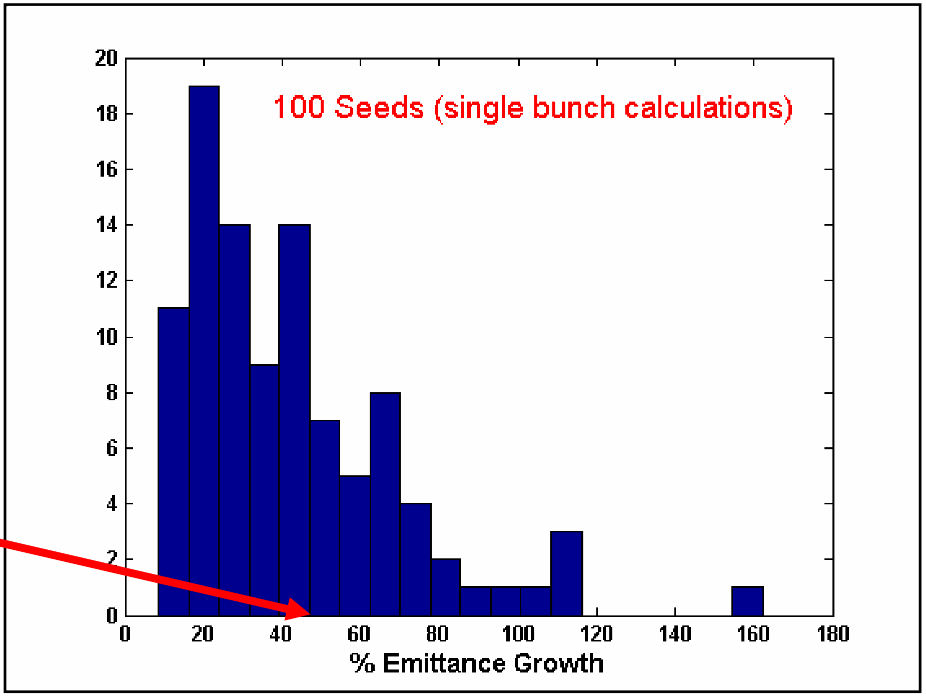
QMUL High-Throughput Cluster

- **QMUL Test GRID cluster- http://194.36.10.1/cluster**
- **Boxes run Redhat 9 Linux – have 100 Unix Matlab licenses.**

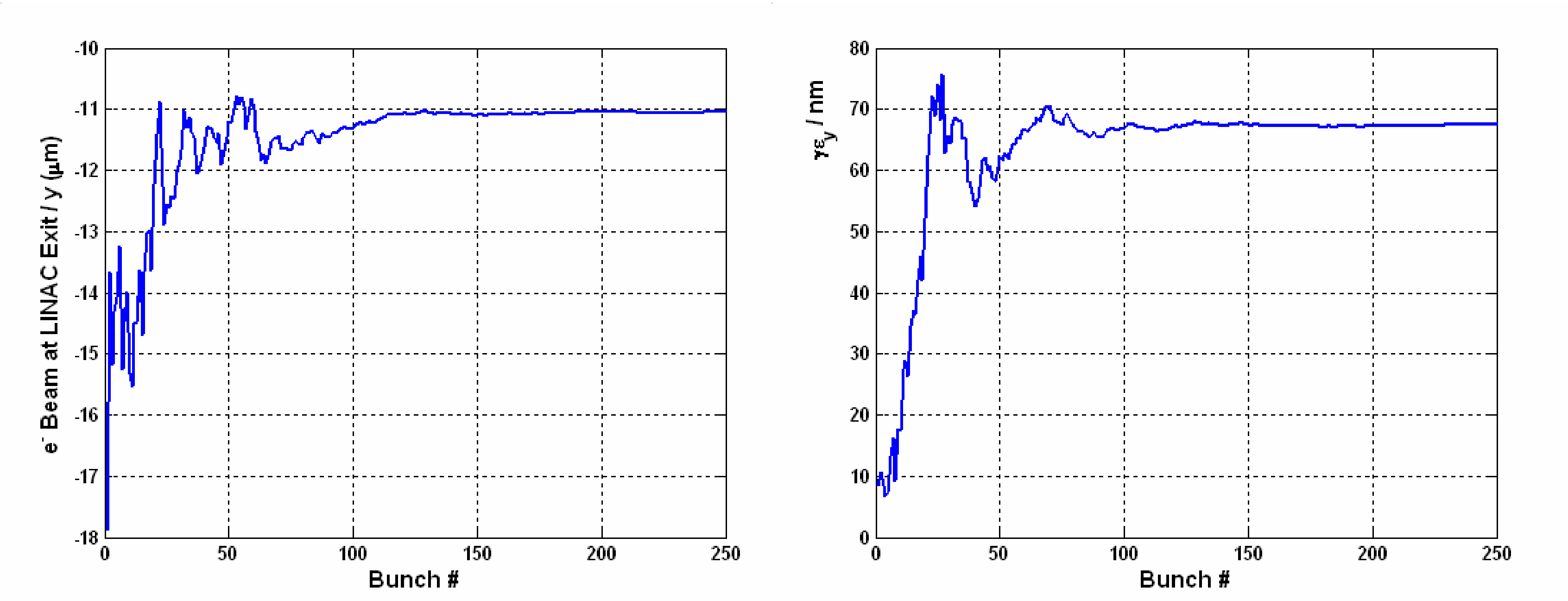
Linac Simulation

PLACET:

- Structure Misalignment: 0.5mm RMS y, 0.3mrad y' error.
- BPM misalignment: 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).



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.**

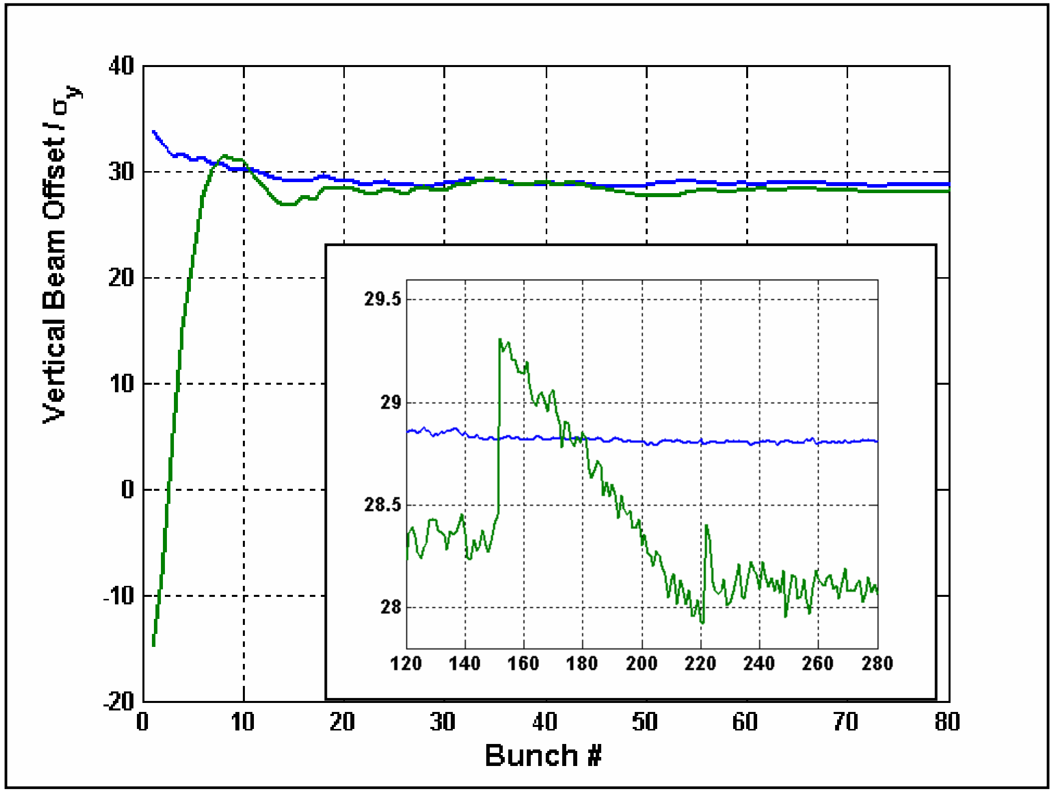
•Feedback (Simulink model in Matlab):

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

•IP (Guinea-Pig):

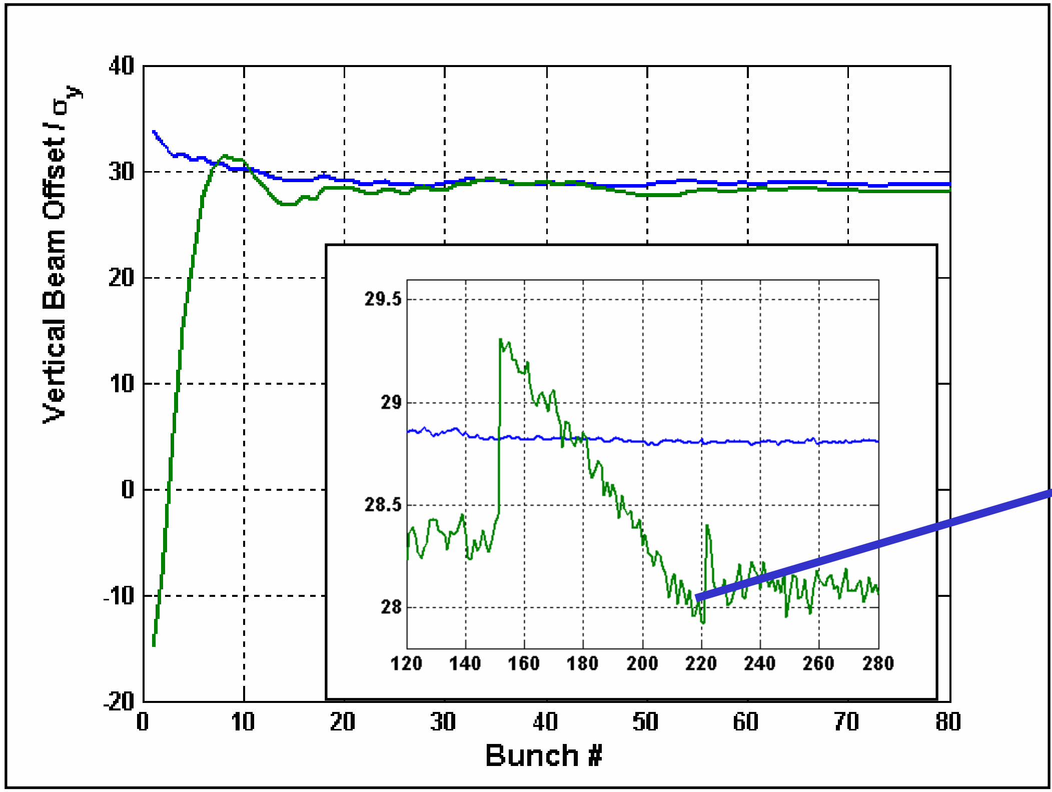
- **•Input macro-beam from MatMerlin BDS (non-gaussian).**
- **•Calculates Lumi & Beam-Beam kick.**
- **•Produces e^+e^- pairs -> track through solenoid field and count number hitting LCAL first layer for Lumi FB signal.**

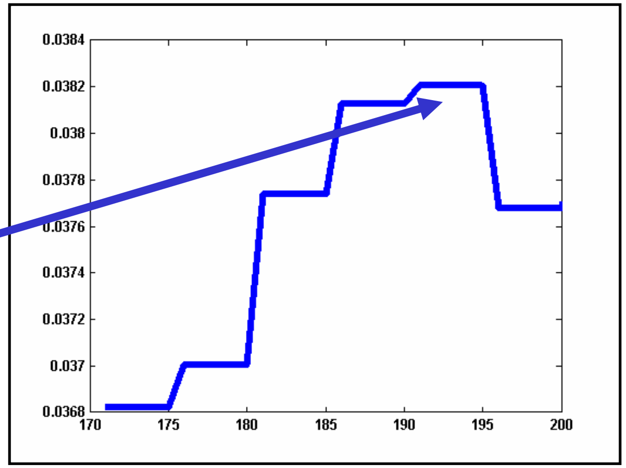
IP Feedback



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

IP Feedback

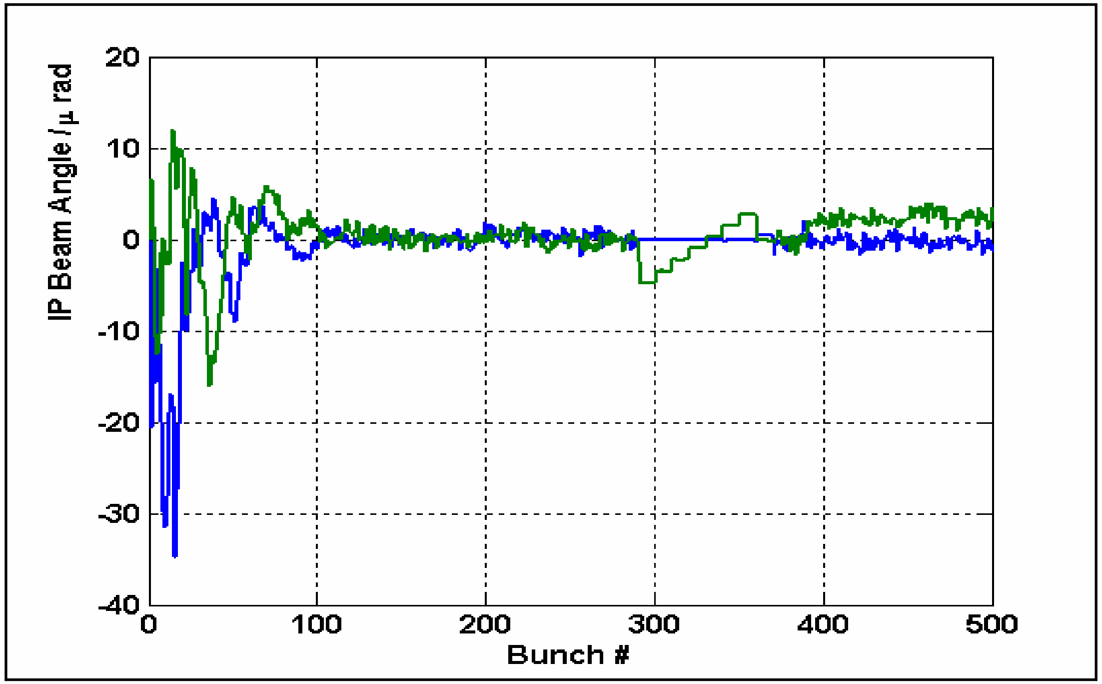




5 Bunch e^+e^- Int. Signal

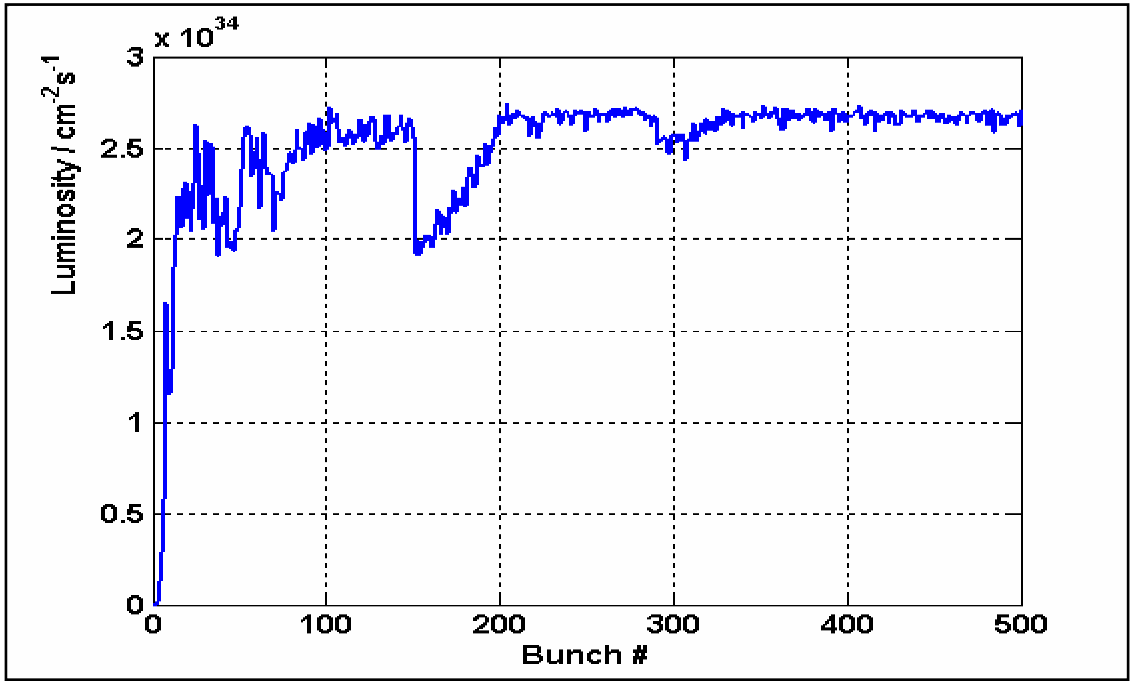
- **Corrects < 10 bunches.**
- **Corrects to finite Δy due to banana bunch effect.**
- **Vertical Beam-Beam scan @ bunch 150.**

Angle Feedback



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

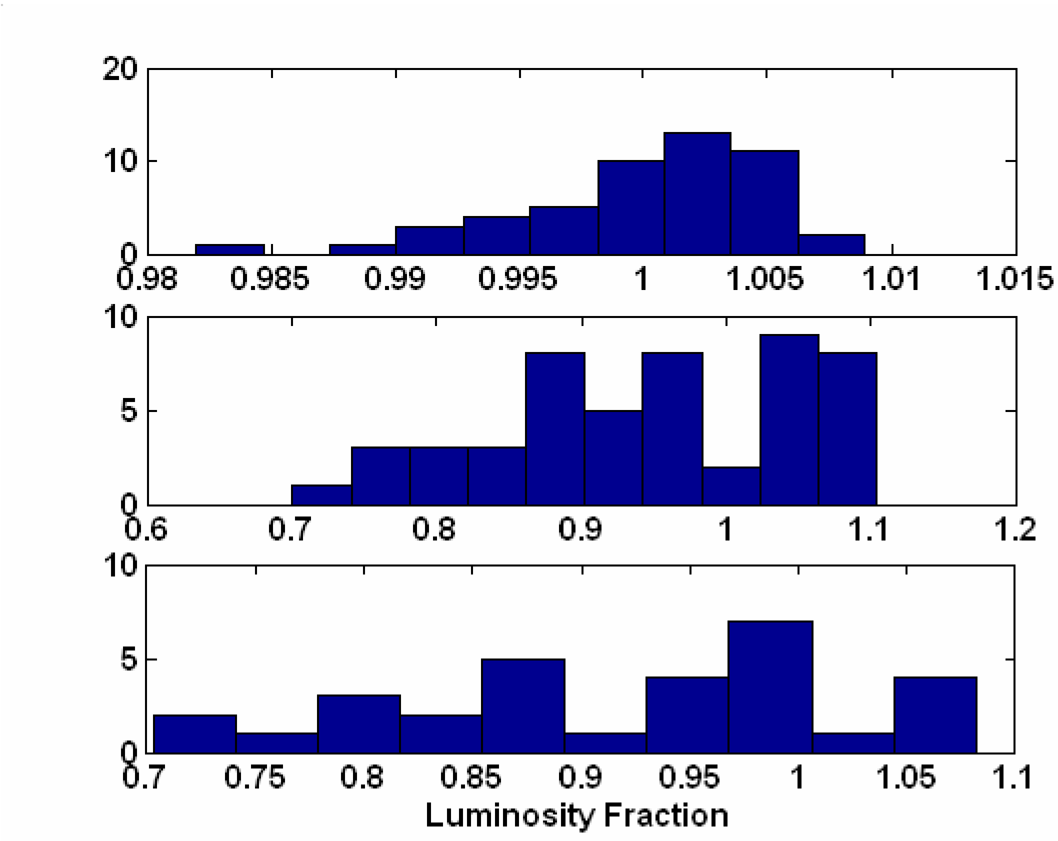
Luminosity



•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

$\mu = 1.0 \pm 0.005$

GM (35nm BDS, 100nm Linac)

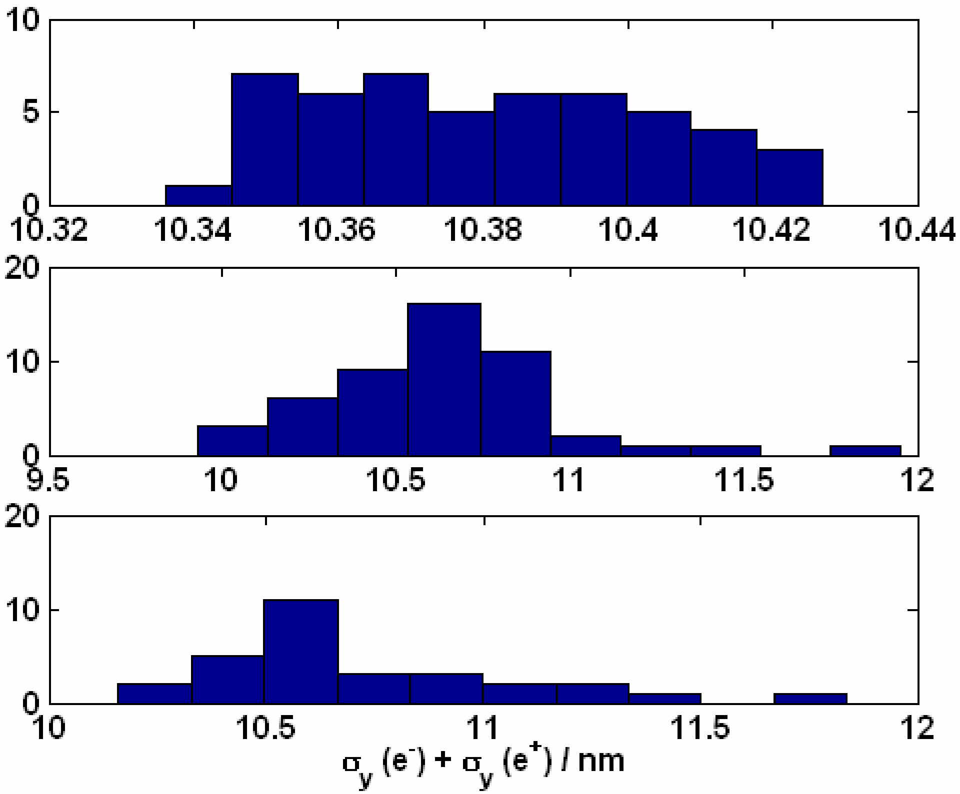
$\mu = 0.95 \pm 0.1$

GM + 0.2σ 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)

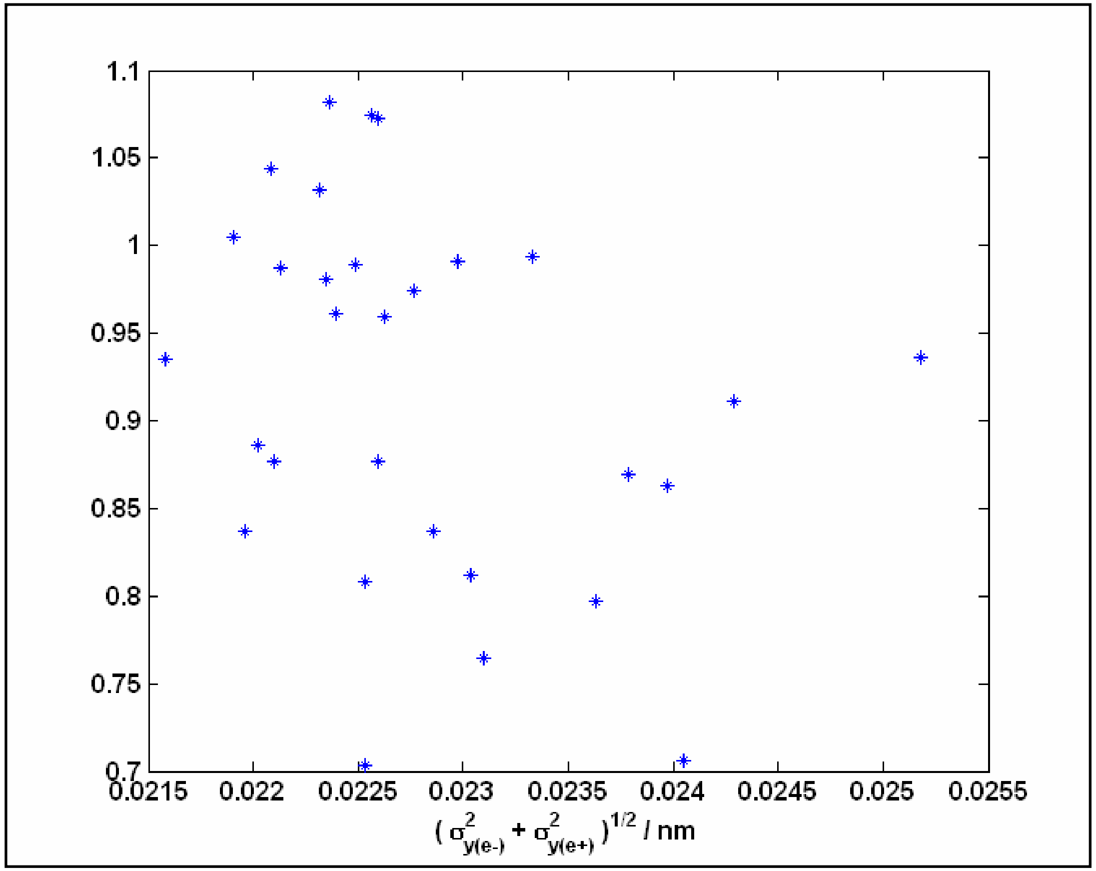
$\mu = 10.6 \pm 0.3$

GM + 0.2σ Inj. Jit

$\mu = 10.7 \pm 0.4$

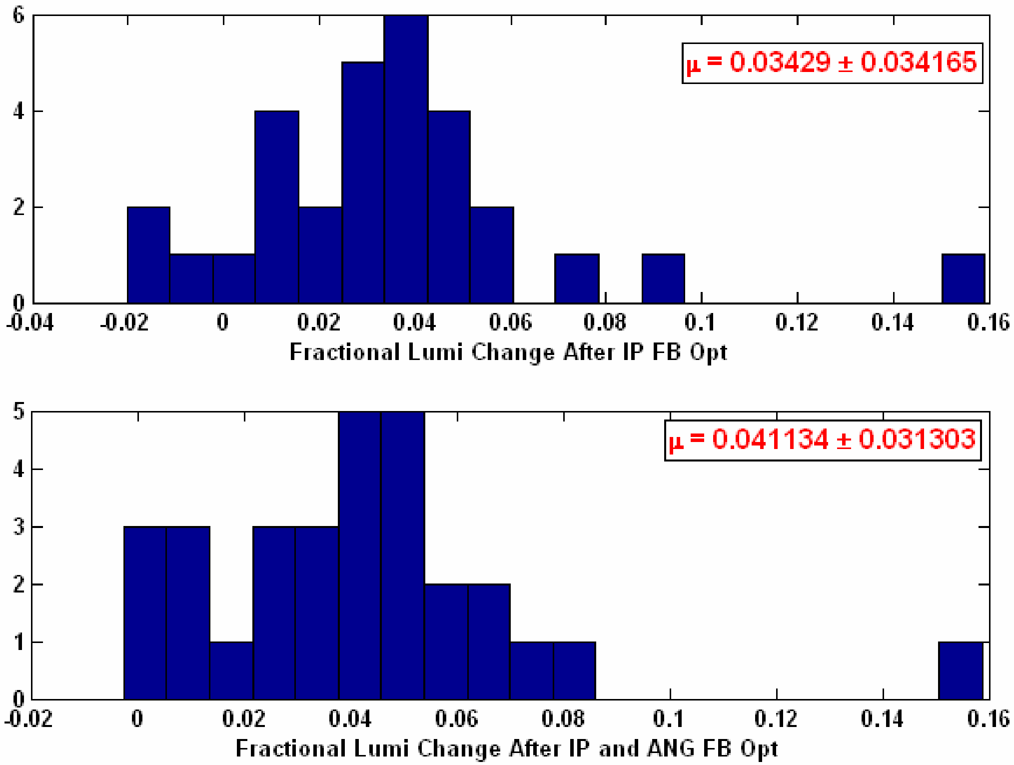
- **Sum of Vertical IP Bunch Spot Sizes.**

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?**

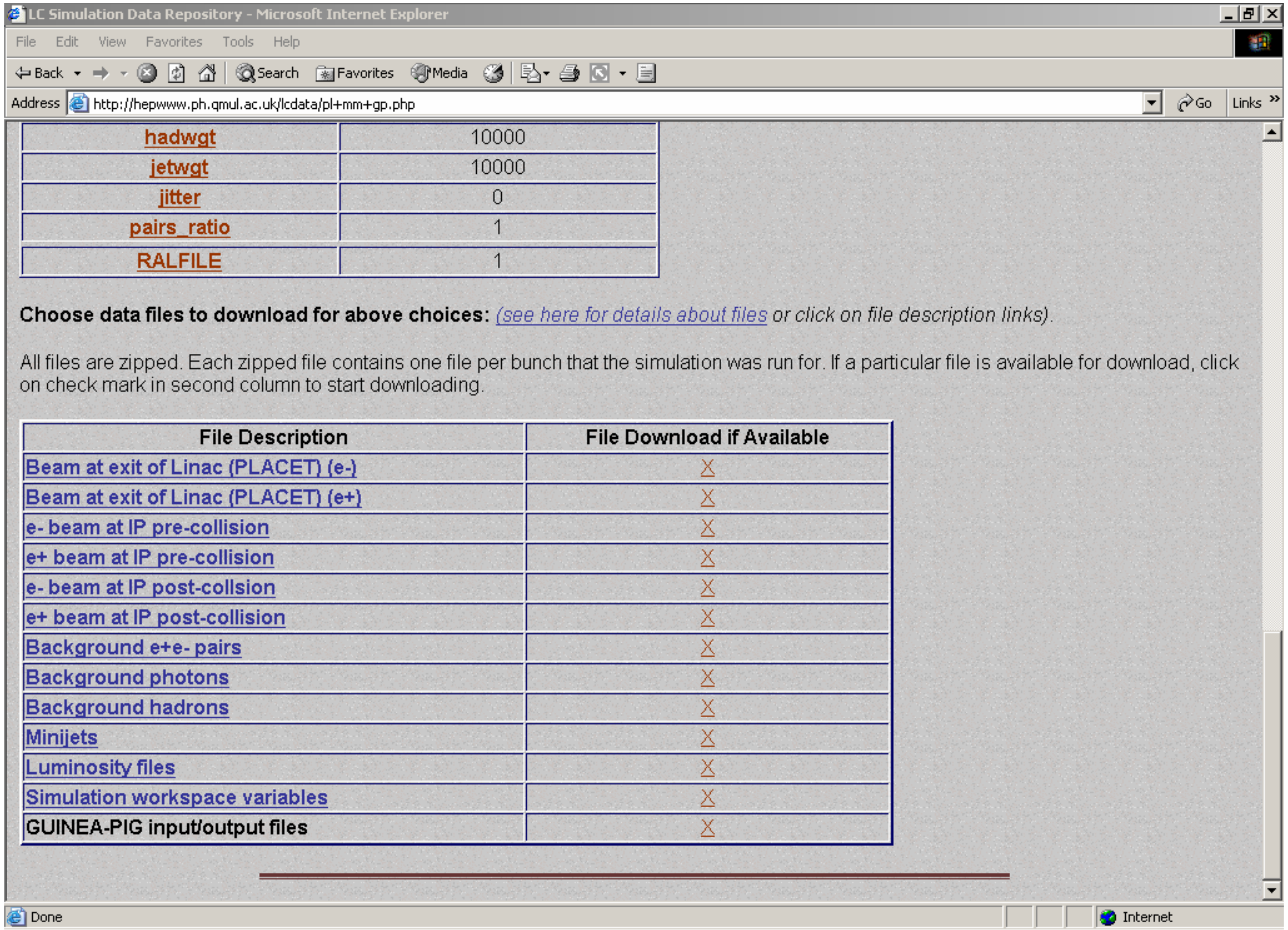
Effect of Lumi-Scan



- 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 σ RMS Injection error data.

LC Simulation Web Page



LC Simulation Data Repository - Microsoft Internet Explorer

Address http://hepwww.ph.qmul.ac.uk/lcdata/pl+mm+gp.php

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-collsion	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.
    - 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).