Integrated Luminosity Performance Study on the ILC – WP6

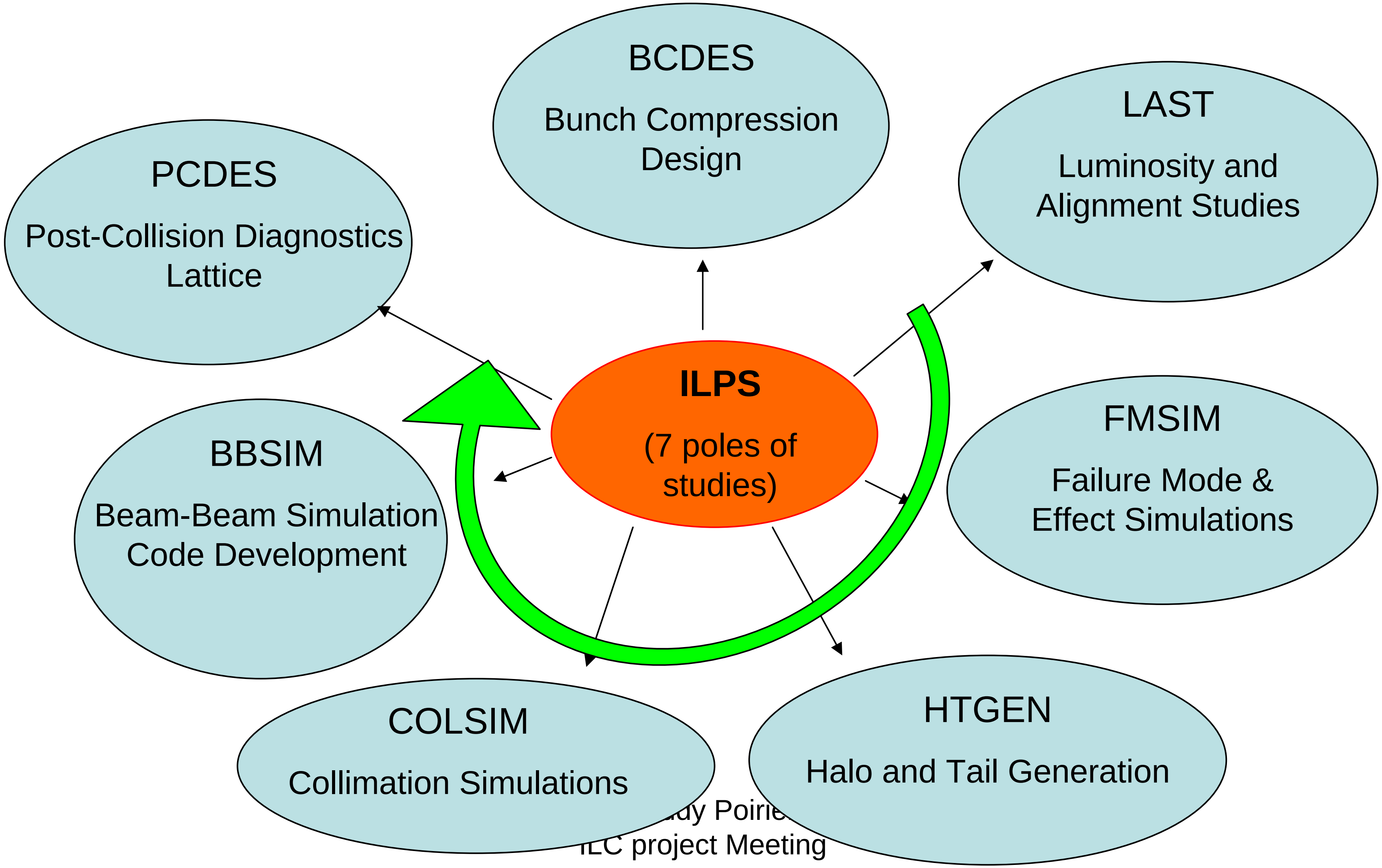
(A snapshot of the European LC workshop at Daresbury)

Freddy Poirier

ILPS – WP6

- A central aim of WP6 is to
  - provide the required reliable computer models to study the machine performance with a wide variety of static and dynamic imperfections.
  - A second area of activity is the modelling of beam halo generation, and the performance of the halo collimation systems necessary to shield the physics detector from unacceptable background.
  - A final step is to amalgamate the two studies (codes), enabling us to study the impact of errors, luminosity tuning and feedback systems on halo-induced background and background tuning.
- More tasks (see next slide)

ILPS tasks



ILPS
(7 poles of studies)
BCDES
Bunch Compression Design
LAST
Luminosity and Alignment Studies
FMSIM
Failure Mode & Effect Simulations
HTGEN
Halo and Tail Generation
COLSIM
Collimation Simulations
BBSIM
Beam-Beam Simulation Code Development
PCDES
Post-Collision Diagnostics Lattice

European LC workshop

- At Daresbury Laboratory (UK) 8th til the 11th of January 2007
  - 2 first days the ILPS was combined with BDS and ILC-LET
  - 2 last days focused on the ILPS and ILC-LET
  - Mainly on ILC (also CLIC)
- Snapshot of the present studies within the WP6

ILPS at The European Linear Collider Workshop

Monday

ILPS/ILC-LET

BDS –

ILPS LET combined

- **Recent Studies on the ILC Main Linac with MERLIN**
- Integrated Dynamical Simulation of Dispersion Free Steering
- Main Linac Simulations Including Emittance Tuning Knobs
- Status of Integrated Simulations based on PLACET
- **Halo and Tail Generation Studies**
- **ILC Collimation simulations and optimisation**
- **Electromagnetic simulations for SLAC ESA beam tests**
- **ESA Wakefield T480 run and results**

Tuesday

BDS - ILPS/ LET combined

- Dynamic Simulations
- **Development and improvement of the guinea-pig beam-beam simulation**
- Comparison of e+e- and e-e- modes of operation with realistic errors in the BDS
- Improvements of the CLIC beam delivery system
- Study of the CLIC Beam Delivery System
- **Status of the Head-on Interaction Region**
- Recent improvements of BDSIM
- **Recent Improvements of PLACET**
- Implementation of Higher Order Mode Wakefields in Merlin
- Calculation and Implementation of collimator Wakefields into PLACET

32 talks over 4 days

Wednesday:

ILPS/ILC-LET

BC

RTML

ATF 2

BDS

- Pathlength Feedback for CLIC
- **Bunch Compressor Alignment**
- Latest Results for the Final CLIC Main Beam Bunch Compressor
- Kick Minimization steering in ILC bunch compressor, preliminary simulation
- RTML tuning*2
- Introduction to ATF2 beam tuning
- ATF2 Extraction Line
- ATF2 tuning simulation
- Lattice Design of BDS (phone)
- BDS beam based alignment
- **BDS tuning simulation**

Thursday:

BDS

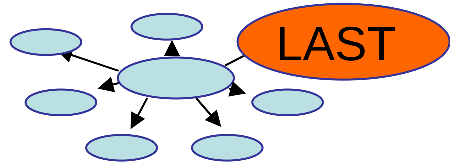
Main Linac

LET

- Lattice Design of Main Linac
- Review of undulator section of e- main linac for e+ source
- Kick Minimization steering in undulator section
- **Summary of Code Benchmark**
- Adaptive alignment and Ground Motion
- Emittance Tuning Bumps

Freddy Poirier

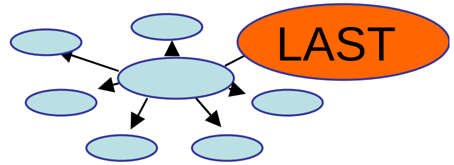
ELC workshop: http://ilcagenda.linearcollider.org/conferenceTimeTable.py?confId=1265



LAST task

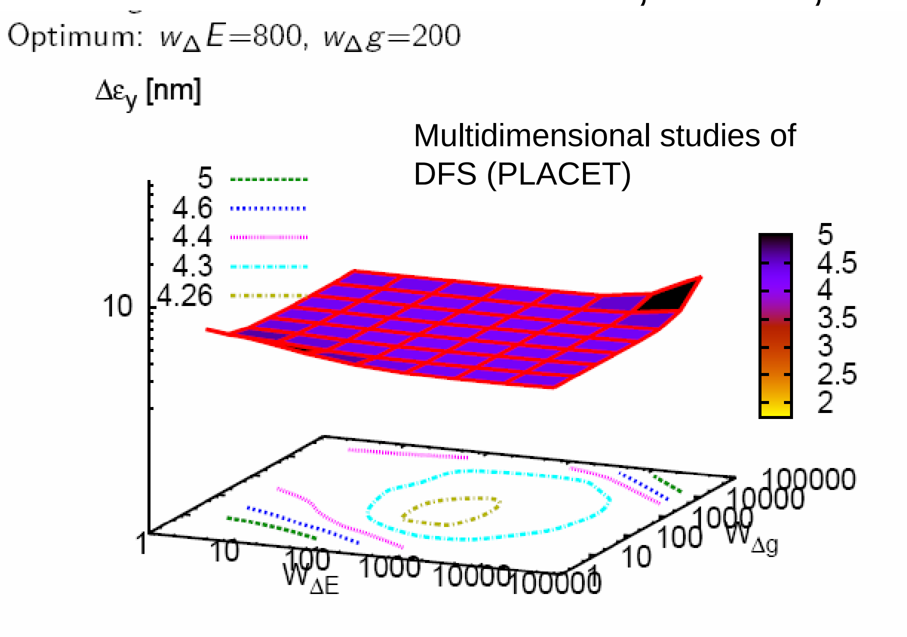
- LAST: Luminosity and Alignment Studies
  - Big chunk of the workshop
  - Involved international contribution with presentations from SLAC, FERMILAB, KEK
  - Encompasses investigation on Simulation of Bunch Compressor (BC), Main Linac (ML), Beam Delivery System (BDS).
  - Included Tuning Strategy.
- Emittance budget:
  - RTML: 4nm
  - ML: 10nm
  - BDS: 6nm

  } Not confirmed! Still under discussion
- Lattice:
  - Several different are used (not standardised!)
  - 2006e release (BDS, ML) → http://www.slac.stanford.edu/~mdw/ILC/2006e



Main Linac

- Static (misalignment) studies under scrutiny:
  - Several type of Beam Based Alignment
    - Dispersion Free Steering most widely used
      - Various Algorithm
      - Various Codes (MERLIN, PLACET, MATLIAR, BMAD, ELEGANT, CHEF, SLEPT)



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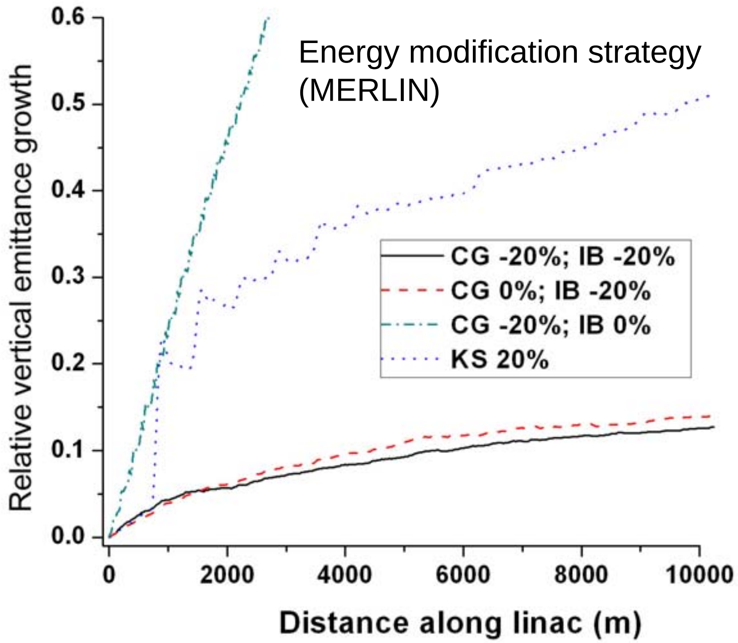
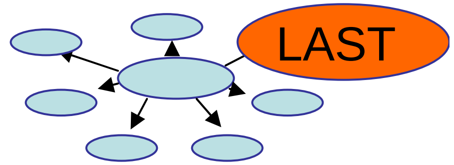
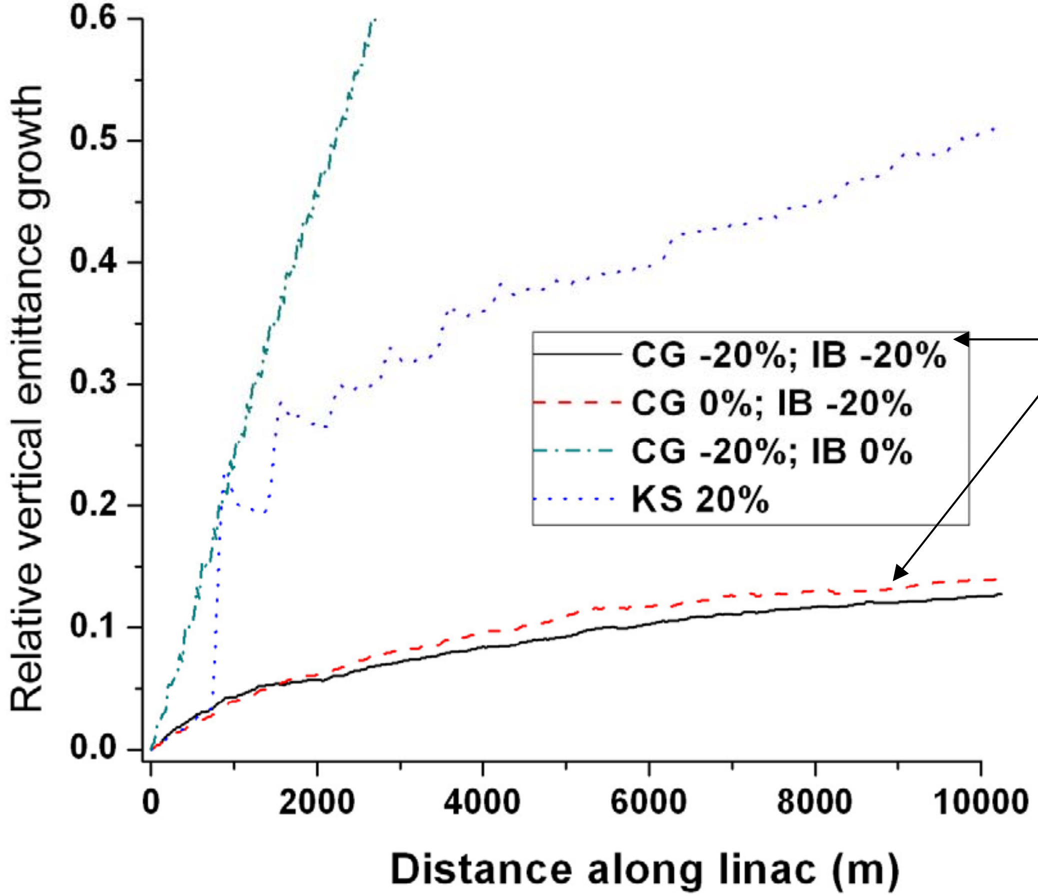




DFS in Main Linac

Energy modification strategy (MERLIN)



Initial beam adjustment most effective to keep the emittance growth low

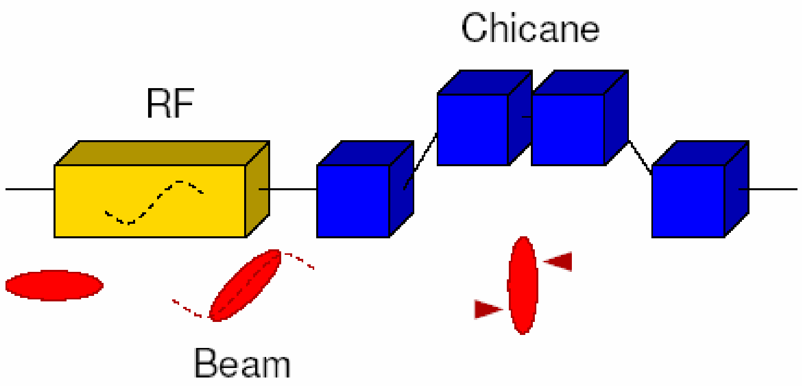
How to do this in the real machine?

KS: Krystron shunting
CG: constant gradient
IB: Initial beam adjustment

Recent studies on the ilc ml using MERLIN, F.Poirier

Bunch Compressor

- In order to compress a bunch longitudinally we need to impress a "rotation" in the longitudinal phase space
- this is achieved by two *pseudo*-rotations :



BC: 2 stages compression

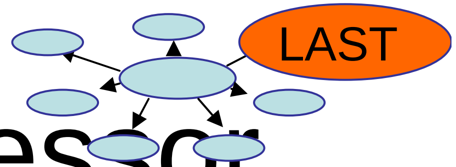
-σ_z reduced from 6 mm → 300 μm

- Energy increased from 5 GeV → 15 GeV

for which we need :

1. a RF system, working at a phase equal to $k\pi$, that linearly correlates the momentum with the z-position of the particles in the bunch

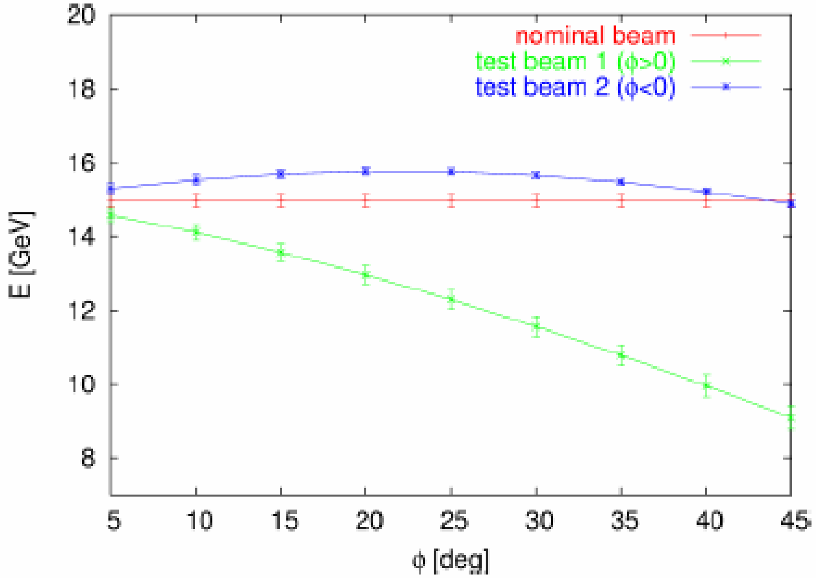
2. a magnetic chicane that provides a convenient R_{56}. The magnetic chicane consists of two pairs of rectangular dipoles, one being the mirror image of the other, separated by a drift space (see Frank Stulle's talk, CLIC Meeting, October 6, 2006)

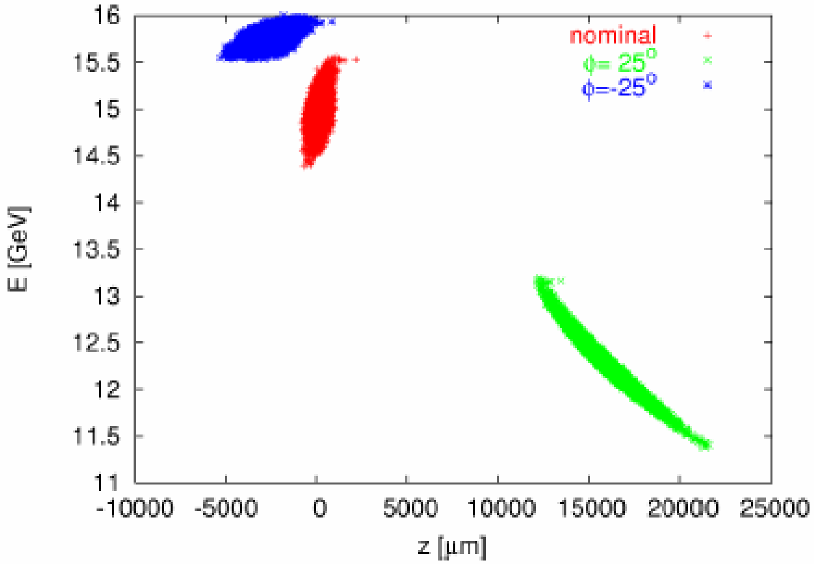


Using the Bunch Compressor

BC used to modify the energy at entrance of ML (needed for DFS)

Energy difference as a function of the phase:



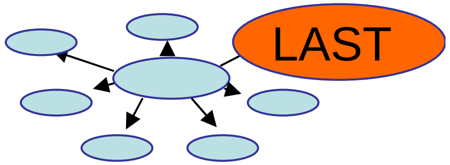


- with respect to the nominal beam, off-phase beams have:
  - different energy spread
  - greater bunch length
  - phase out of sync
- their phase must be synchronized with the ML accelerating phase

BC for generating beam energy difference seems to work

Used with DFS in ML gives very small emittance growth for a straight linac (~2nm)

NJW1



Main Linac

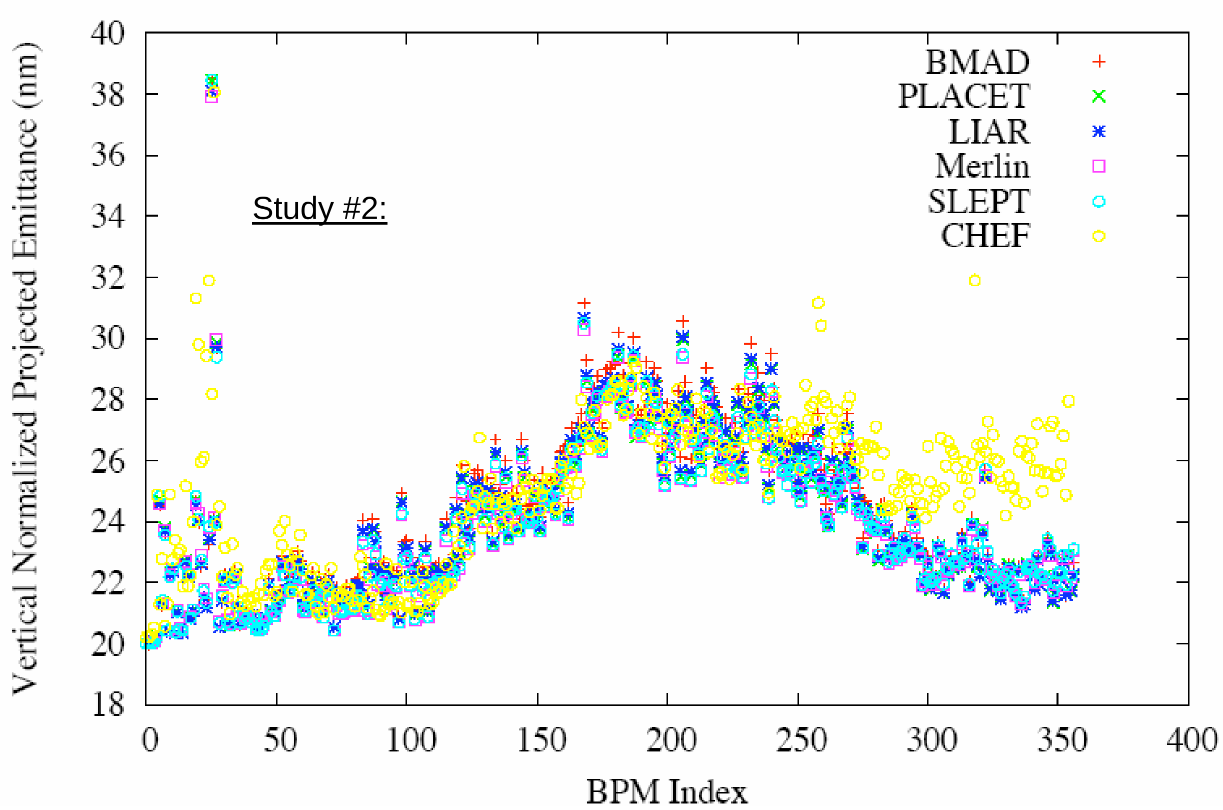
- A series of Benchmark was done:

Study #2:

One code used to generate a set of correctors after DFS applied.

This benchmark compares the tracking codes

All codes pretty well agree →1 not and is under investigation



Further Benchmark done:

Codes run also independent DFS (with same misalignments):

No significant difference in performance (Emittance growth)

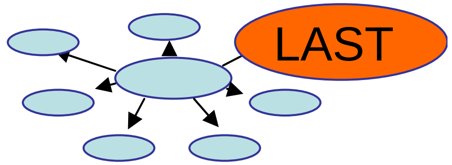
Summary of code benchmarking, J. Smith

Slide 11

NJW1 One code (MATLIAR) used to generate corrector settings after DFS.

This benchmarking compares the tracking codes (using same errors and corrector settings).

Nicholas Walker, 1/25/2007



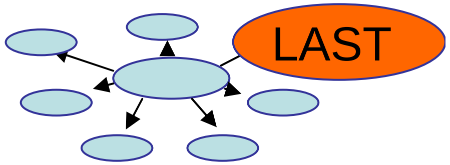
Main Linac

Static simulation:

Conclusions

⇒ The curved and laser-straight layouts give comparable performances

- In case of a curved linac, beware of BPM calibration errors:
  - they can significantly impact the performance of beam-based alignment
    - ⇒ with a BPM resolution, σ_{res}, of 10 μm a scale error up to 10% is acceptable
    - ⇒ better resolutions magnify the impact of this error but, on the other hand, allow to reduce the energy difference between test and nominal beam



BDS

- Demonstrate can tune-up ILC BDS from expected post initial survey conditions to nominal luminosity.
- Try and "keep it real".
- Simulation models:
  - Magnet – BPM alignment.
  - Beam-Based alignment using magnet movers.
  - Luminosity tuning using Sextupole multi-knobs.
  - 5-Hz trajectory feedback to maintain orbit in FFS Sextupoles.

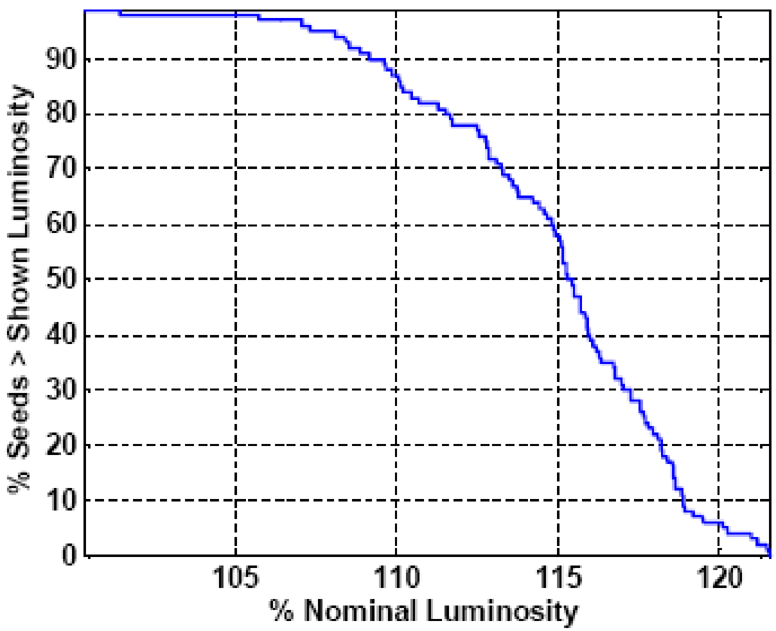
Initial beam:

- Beam enters BDS on-axis with 10um/34nm horizontal/vertical normalised emittances (6nm vertical emittance-growth budget).

ILC BDS Beam Based Alignment and Tuning, G. White

BDS

Achieved luminosity



Tuning performed on luminosity calculated by colliding bunch with itself with GUINEA-PIG.

- All the random seeds tuned to give greater than the required nominal luminosity.
- The median result gives a 15% luminosity overhead after tuning.
- This sets the performance requirements for the feedback systems used to maintain luminosity in the presence of ground motion and component vibrations.

Lumi. Overhead eaten by bunch-bunch effects and slow luminosity degradation

ILC BDS Beam Based Alignment and Tuning, G. White

FMSIM task

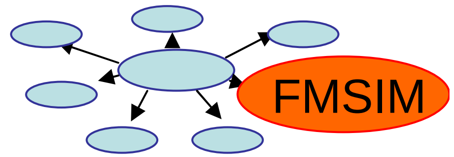
Main Linac

Failure Modes

- Failures in the ILC can lead to beam loss or damage the machine
- The main linac is the most expensive subsystem of the ILC, therefore even a seldom failure scenario may be worth considering

- We considered the failure of the klystron phase
  - a change in the klystron phase will modify the acceleration
  - the deviation from the design orbit can become too large and the beam becomes instable
  - here we consider the case that the phase for all klystrons is changed by a common offset

Recent Improvement in Placet, A. Latina, D.Schulte

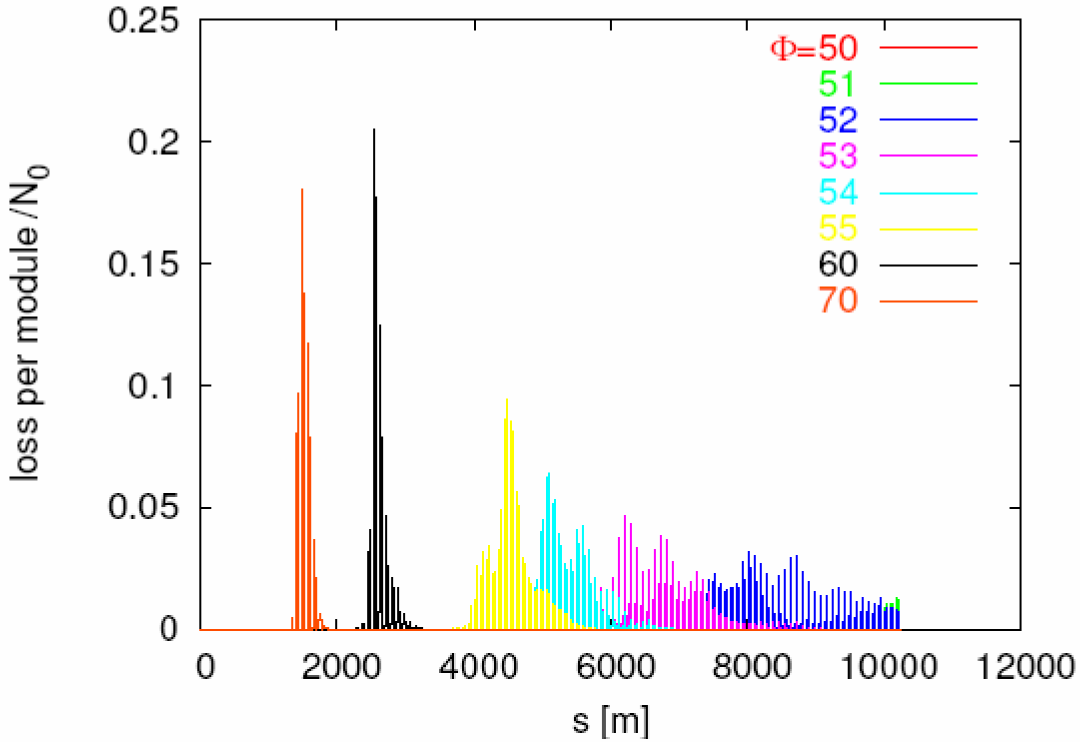


Failure Modes (2)

Main Linac

Failure Modes in the Main Linac

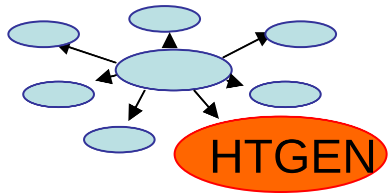
Spatial distribution of lost particles for different klystrons phase shifts



→ confirmed previous DESY studies

Potential for beam related damage to the superconducting RF cavities is minimal

HTGEN task

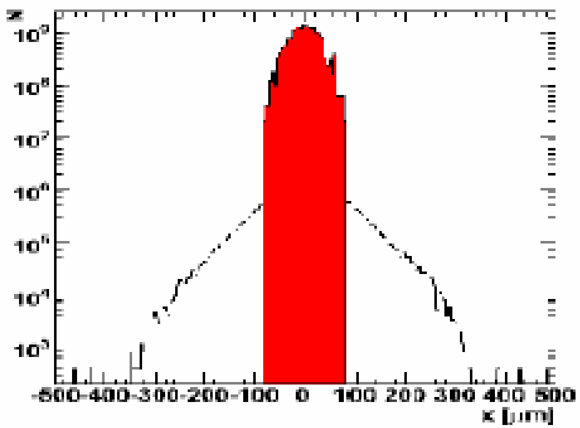


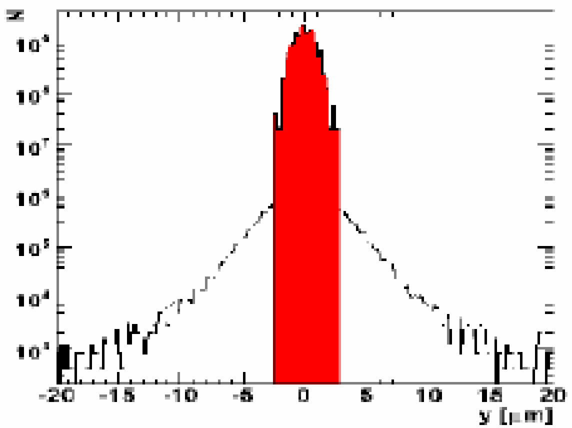
- study of potential sources of halo and tail generation in Linear colliders with development of analytical models of halo, estimates of halo population, development of computer models for halo/ tail generation, simulation studies of halo/tail generation and benchmarking HTGEN

Investigation of several particle processes.

Example application: beam gas

Particle above $10\sigma_{core}$ represent 10e-5 of total

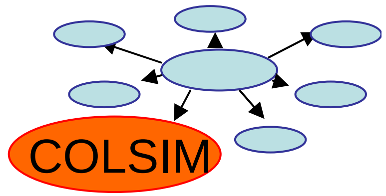




Nominal vacuum in BDS leads to 10^3 losses/bunch

- 50 nTorr @ 300 K in the first section
- 10 nTorr @ 2K in the last final doublet

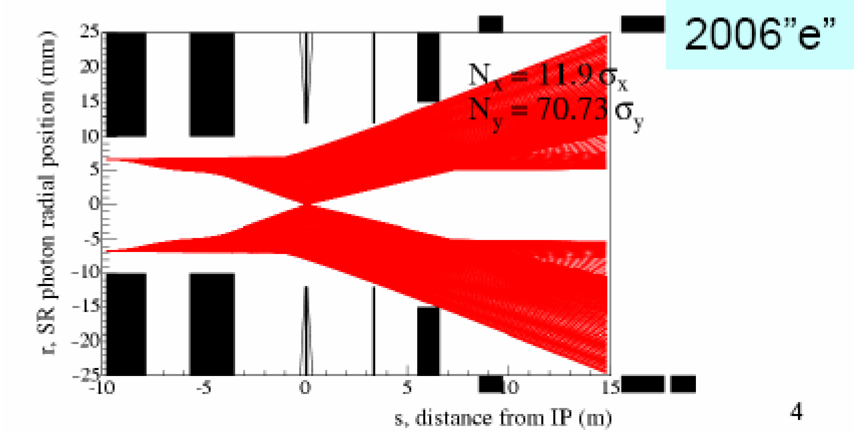
This represents ~ $5x10^5$ muons / bunch train produced



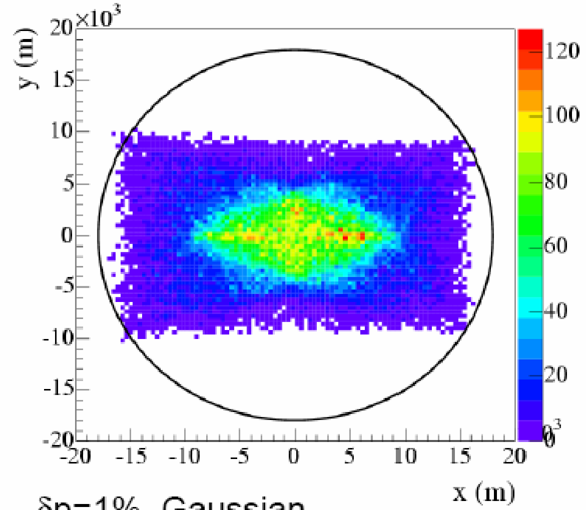
COLSIM task

- *simulation of post-linac beam halo collimation,*
  estimation of collimator efficiency,
  optimisation of collimation system,
  simulations of muon and neutron production in collimator sections,
  estimates of impact of physics detector performance,
  studies of muon and neutron production,
  impact of luminosity tuning on halo collimation efficiency
- Collimation design is in a rather mature state (lead by SLAC/FERMILAB)
  - 14mrad crossing angle

BDSIM can track off-energy halo through FD

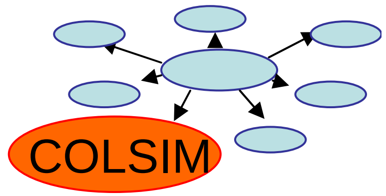


SR profile at 1st Extraction Quad (r=18mm)



δp=1%, Gaussian

Freddy Poirier
ILC project Meeting



COLSIM

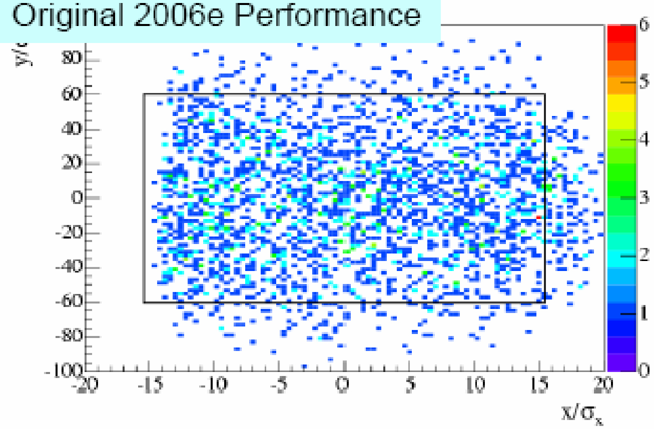
2006e Optimised Performance Tracking Results

- MERLIN BDS halo tracking, "black" spoilers set at nominal collimation depth
- Optimisation gives improved performance, sugges no longer need vertical SPEX collimator

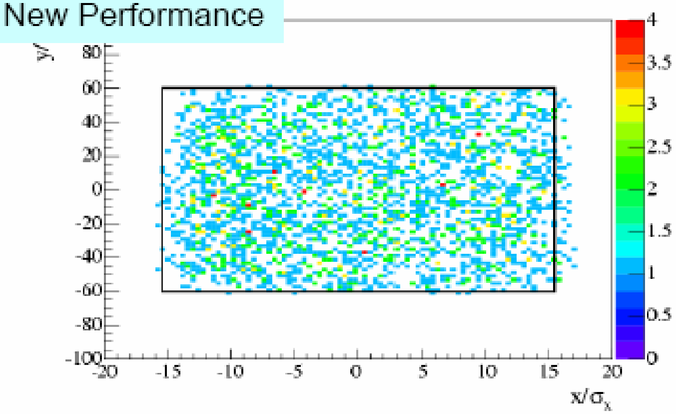
Here optimisation leads to a longer lattice

Same population in both halos at FD

Original 2006e Performance

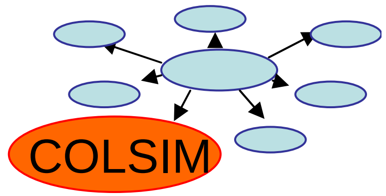


New Performance



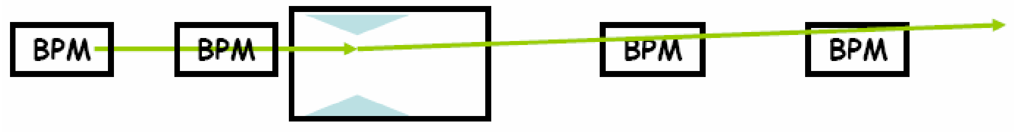
F. Jackson

COLSIM

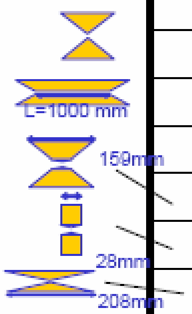


Studies at SLAC ESA of the wakefield generated by collimators → meas. Kick factor

E=28.5GeV



When the collimator is moved the beam is kicked

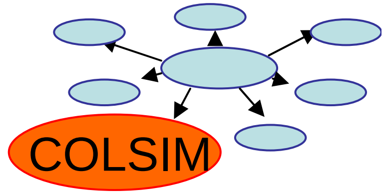


Collimator	Measured[4] Kick Factor V/pc/mm (χ^2/dof) Linear fit	Measured[4] Kick Factor V/pc/mm (χ^2/dof) Linear + Cubic Fit	Analytic Prediction[1] Kick Factor V/pc/mm	3-D Modelling Prediction[2] Kick Factor V/pc/mm
1	1.4 ± 0.1 (1.0)[3]	1.2 ± 0.3 (1.0)	1.1	1.7
2	1.4 ± 0.1 (1.3)	1.2 ± 0.3 (1.4)	2.3	3.1
3	4.4 ± 0.1 (1.5)	3.7 ± 0.3 (0.8)	6.6	7.1
4	0.9 ± 0.2 (0.8)	0.5 ± 0.4 (0.8)	0.3	0.8
5	1.7 ± 0.3 (2.0)	1.7 ± 0.3 (2.2)	2.3	2.4
6	1.7 ± 0.1 (0.7)	2.2 ± 0.3 (0.5)	2.4	2.7
7	0.9 ± 0.1 (0.9)	0.9 ± 0.3 (1.0)	2.3	2.4
8	3.7 ± 0.1 (7.9)	4.9 ± 0.2 (2.6)	2.3	6.8

[1]Assumes 500-micron bunch length
[2]Assumes 500-micron bunch length, includes analytic resistive wake; modelling in progress
[3]Kick Factor measured for similar collimator described in SLAC-PUB-12086 was (1.3 ± 0.1) V/pc/mm
[4]Still discussing use of linear and linear+cubic fits to extract kick factors and error bars

→ Goal is to measure kick factors to 10%

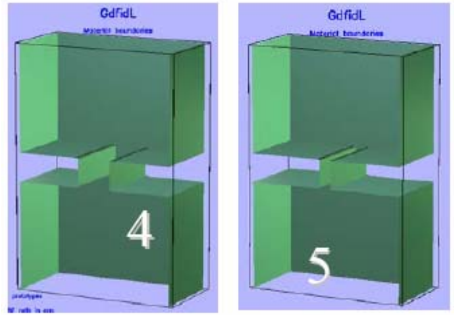
ESA Wakefield T480 run and results, L.Fernandez-Hernando

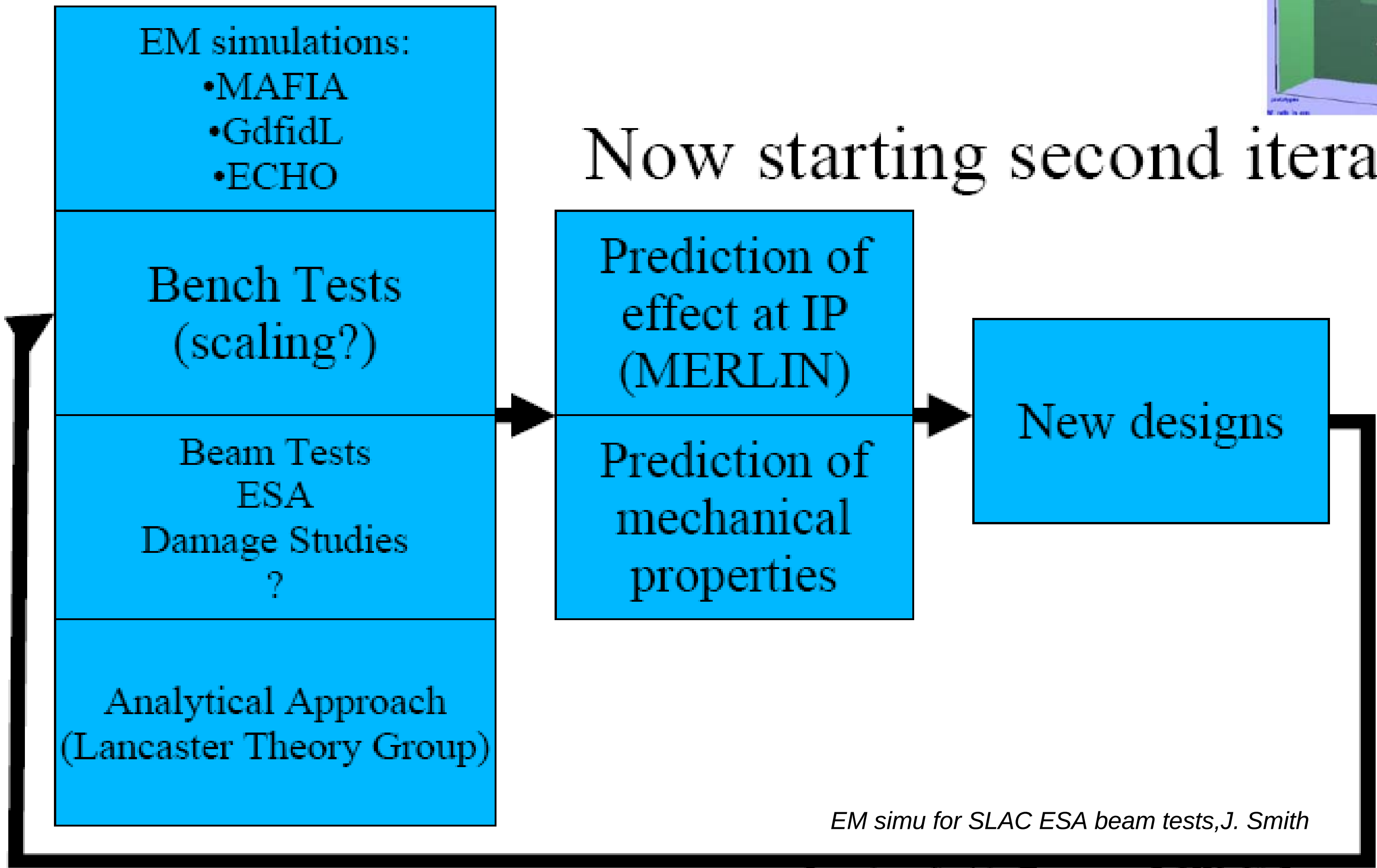


COLSIM

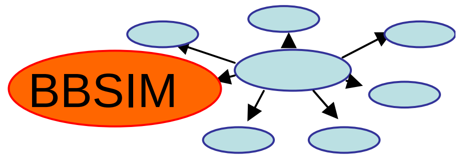
- Study of collimators and wakefields

Several design of collimators have been simulated





EM simu for SLAC ESA beam tests,J. Smith



BBSIM task

- *benchmarking of physics processes in GUINEA-PIG against known and trusted physics generators,*
  implementation of spin transport into GUINEA-PIG

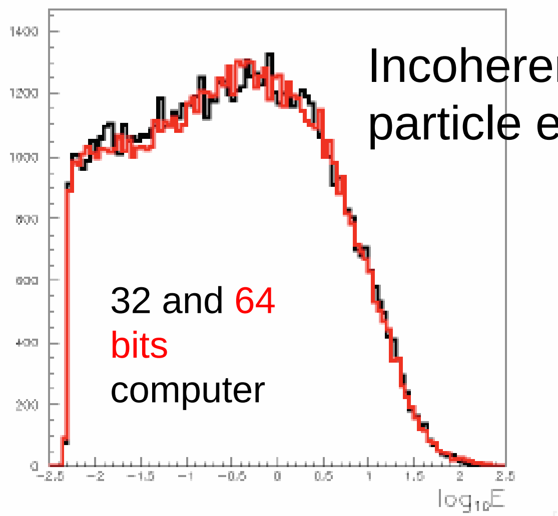
New GUINEA-PIG++ in development https://trac.lal.in2p3.fr/GuineaPig

An object-oriented version of the beam-beam simulation code GUINEA-PIG

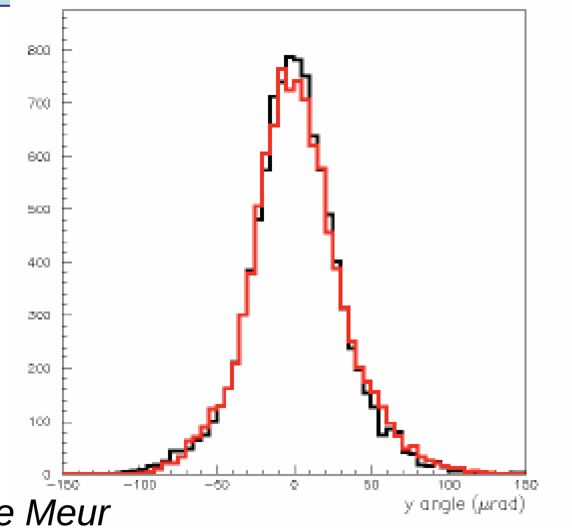
Uses Standard template library (strings, containers)

Some new features (Bhabha deflection, random generator 64 bits), I/O interface, use of grid)

Incoherent pair particle energy E



Particles angles



Developments to come:

Depolarisation effect

Further I/O interface

Head-on Collision

Study of Head-on collision very active:

Head-on makes focusing and colliding easier, while extraction is more difficult

Crossing angle makes extraction easier, while colliding and focusing is more difficult

Head-on IR has the potential to be a **Luminosity** and **Cost** effective option for 500 GeV and 1 TeV ILC

I am optimistic that a **spent beam extraction** system can be found with tolerable beam and beamstrahlung losses

Post-IP instrumentation will be challenging

O.Napoly

Conclusion

- A very active field
  - Several simulation models are used (luminosity and Alignment studies)
    - Being benchmarked, convergent (as more realistic), Static simulation implemented
    - Dynamic is being implemented for start to end machine (rtml→ip)
  - As well tools for simulation of the collimation, wakefields, Halo are being benchmarked, refined, some cross-checked with experiments, and used for optimisation of the machine.

ELC workshop: http://ilcagenda.linearcollider.org/conferenceTimeTable.py?confId=1265