Spin tracking at the ILC

DESY FLC Polarimetry: C.Bartels, M.Beckman, A.Hartin, C.Helebrant, D.Kaefer, J.List, B.Vormwald

- Spin tracking from upstream polarimeter to downstream polarimeter – so BDS and IP and extraction line depolarisation
- BDS & extraction line spin tracking studies using BMAD – consider intertrain, intratrain and intrabunch
- CAIN/Guinea-Pig can be used for IP depolarization, precision spin tracking with bunch field effects can be done using a more exact calculation

Motivation

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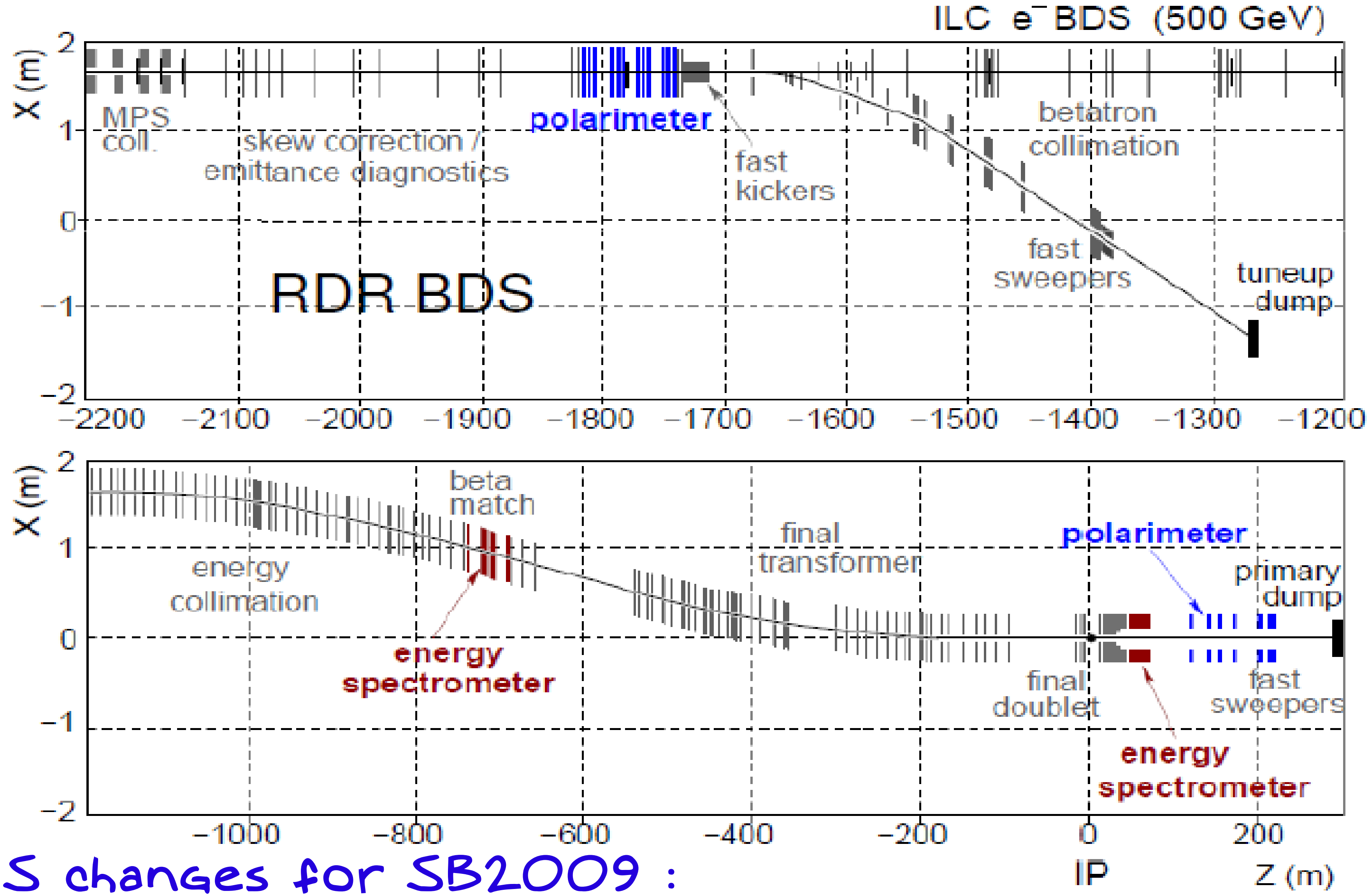
BDS: previous studies [Smith (BMAD) Malysheva (Slicktrack)] show that depol is small, but does it decline over time due to ground motion and on what scale? Mainly classical spin precession here

IP: significant depolarization due to beam-beam effects. Both classical precession and quantum spin flip. The spin-flip calculation assumes classical motion of electron, no beamstrahlung radiation angle. Discuss full calculation

Extraction: Propagate disrupted beam down extraction line and simulate polarization at downstream polarimeter

Time scales: Investigate depolarization within bunch, within train and train-train

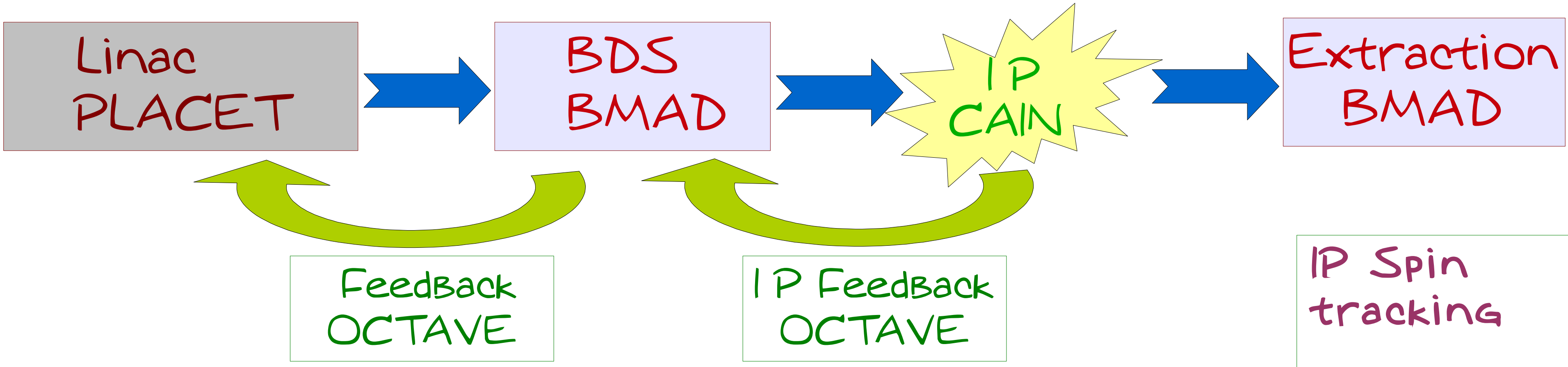
BDS polarimeter siting



- BDS changes for SB2009 :

separate combined functionalities of upstream polarisation measurements + laser wire detection

Simulation components & flow



Placet sim of linac

- 1 micron random displacement
- 1:1 correction
- Dispersion free steering
- Deliver multiple Bunch trains of 300 Bunches

BMAD sim of BDS and Extraction

- Ground motion model applied
- Translate latest ILC MAD lattice
- Examine impact of orbit correction on the induced depolarization

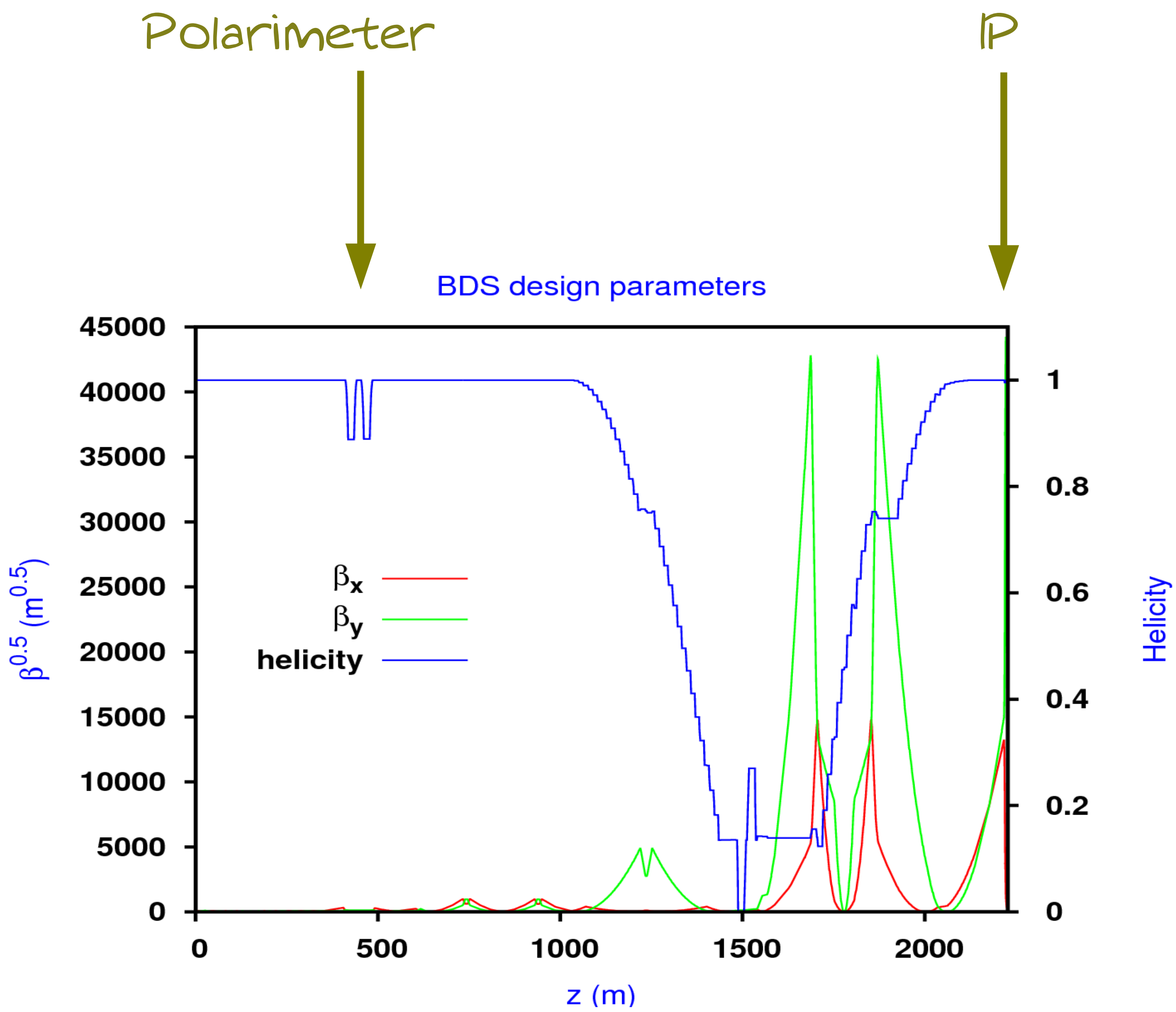
FEEDBACK LOOPS

- Alignment based on beam-beam kicks
- Simple PID controller implemented in Octave
- Bunch to bunch at IP

IP Spin tracking

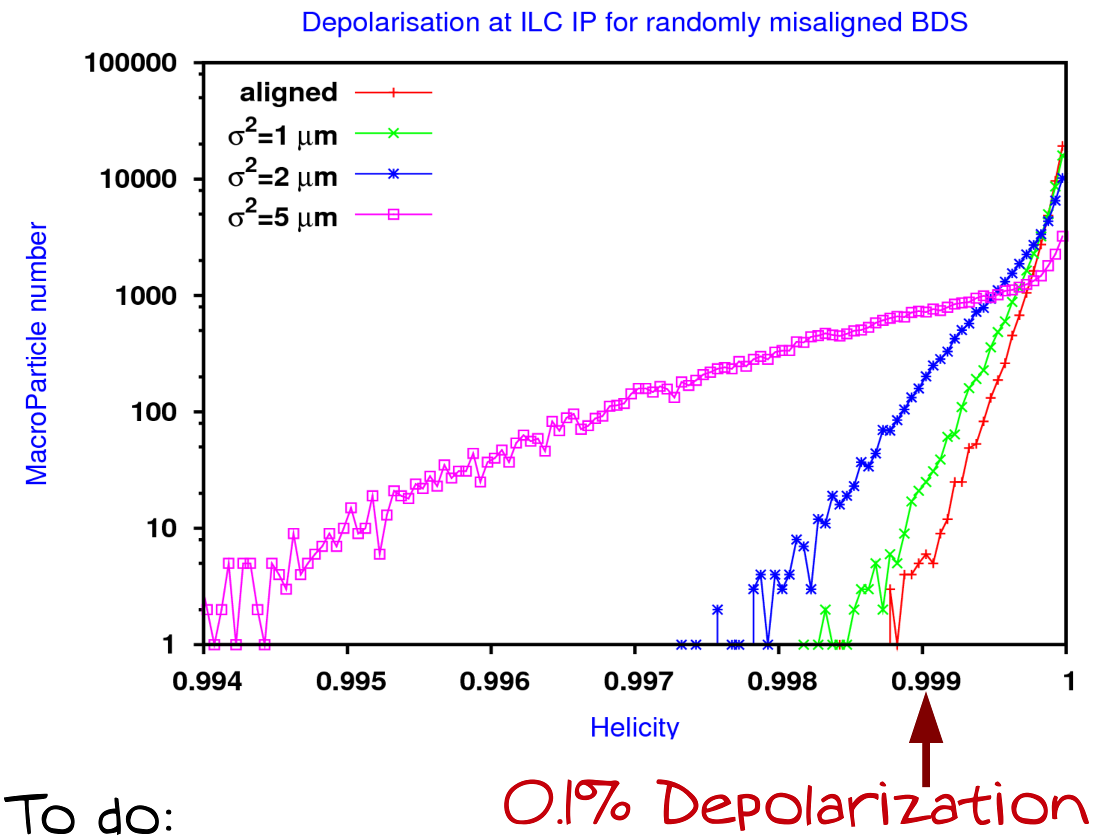
- Modified CAIN with full spin tracking
- Implemented spin tracking in all pair processes
- Full Beamstrahlung calculation (no approximations) investigated

BDS spin tracking



- Lattice translated from MADX to BMAD – checked dispersion and beta functions match TDR
- spin precesses in the latter part of the lattice returning (almost) to original helicity
- Polarimeter and laser wire no longer share the same chicane – waiting on new lattice

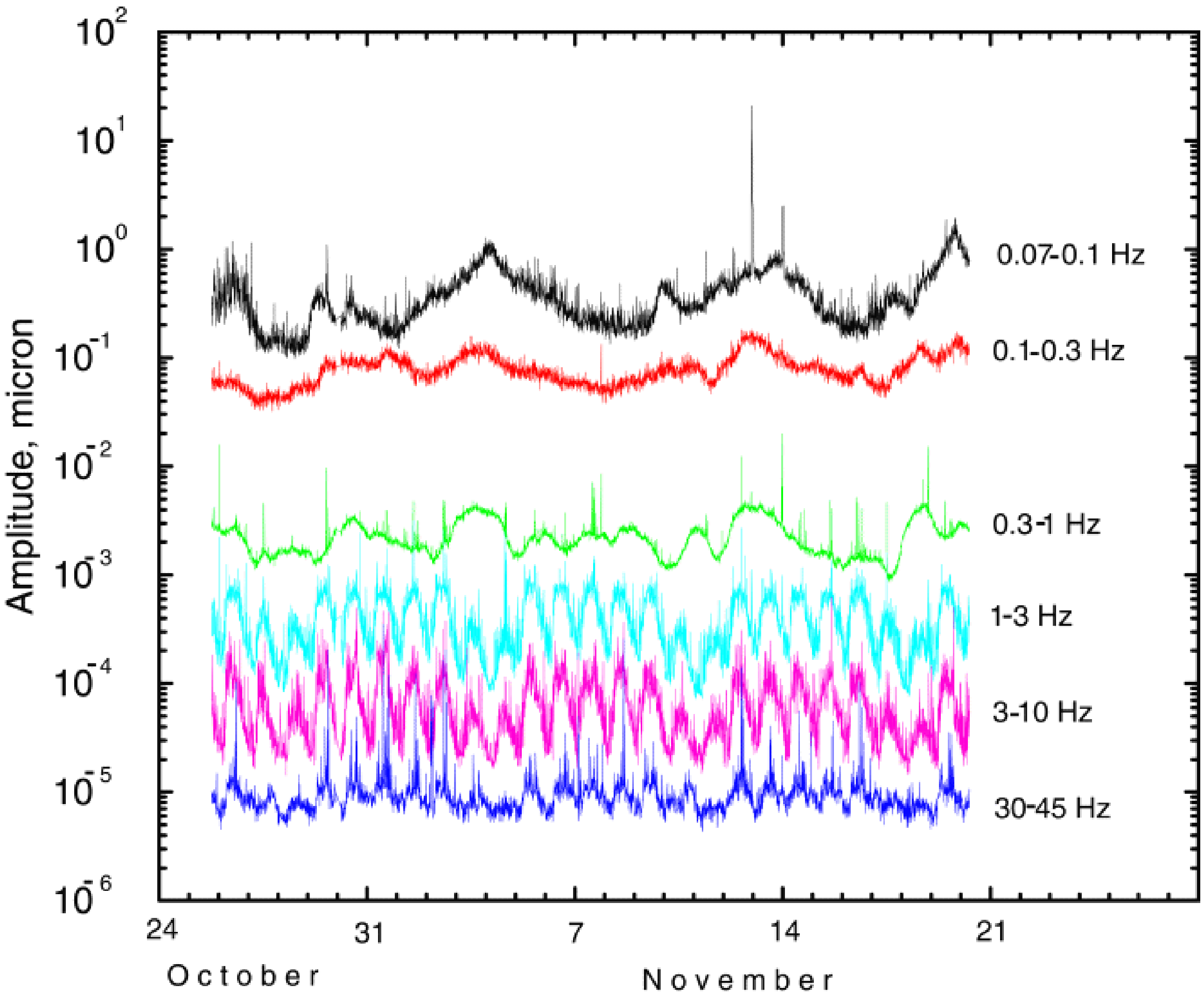
BDS depolarization



- Starting with 100% longitudinal polarization within a single bunch of 50,000 macroparticles
- Introduce misalignments into linac and make 1:1 correction with dispersion free steering to get realistic orbit
- Assume no linac depolarization i
- Make random misalignment of Bds elements in y

- To do:
  - Make realistic misalignments due to expected ground motion
  - Crab cavity is in the lattice only as a drift at present!
  - Examine depolarization recovery with an end-of-linac feedback
  - Track in the extraction line to downstream polarimeter
  - New lattice with polarimeter-only chicane to come

ground motion studies



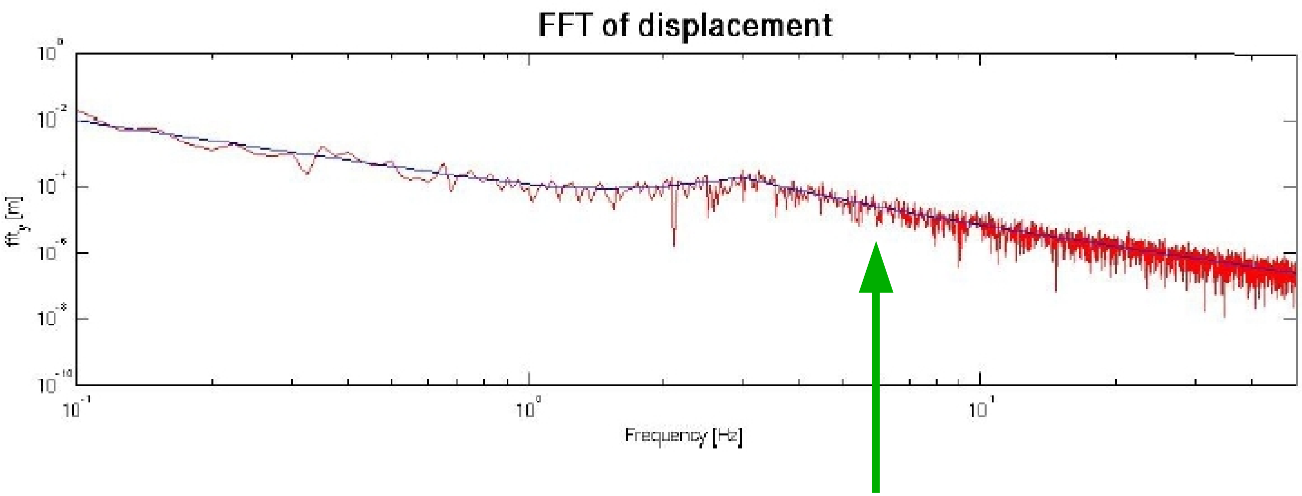
- Small displacements for High frequencies, large displacements (order of microns) for Low frequencies
- We probably do not need to worry about intra-train depolarisation
- Perform detailed ground motion simulations on the scale of hours

Ground motion and misalignments

(Renier and Bambade CARE/ELAN-2007-004)

Schema:

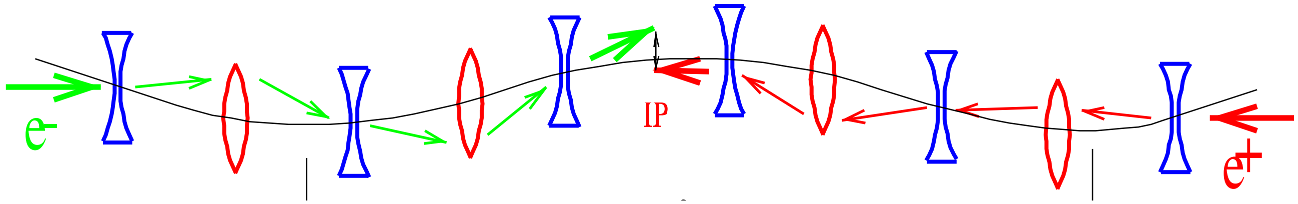
- Real ground motion spectrum measured
- N random offsets generated and transformed into frequency domain
- **Convolute** random and measured spectra and invert transform back to time domain
- Apply coherency function so nearby elements move in a similar fashion

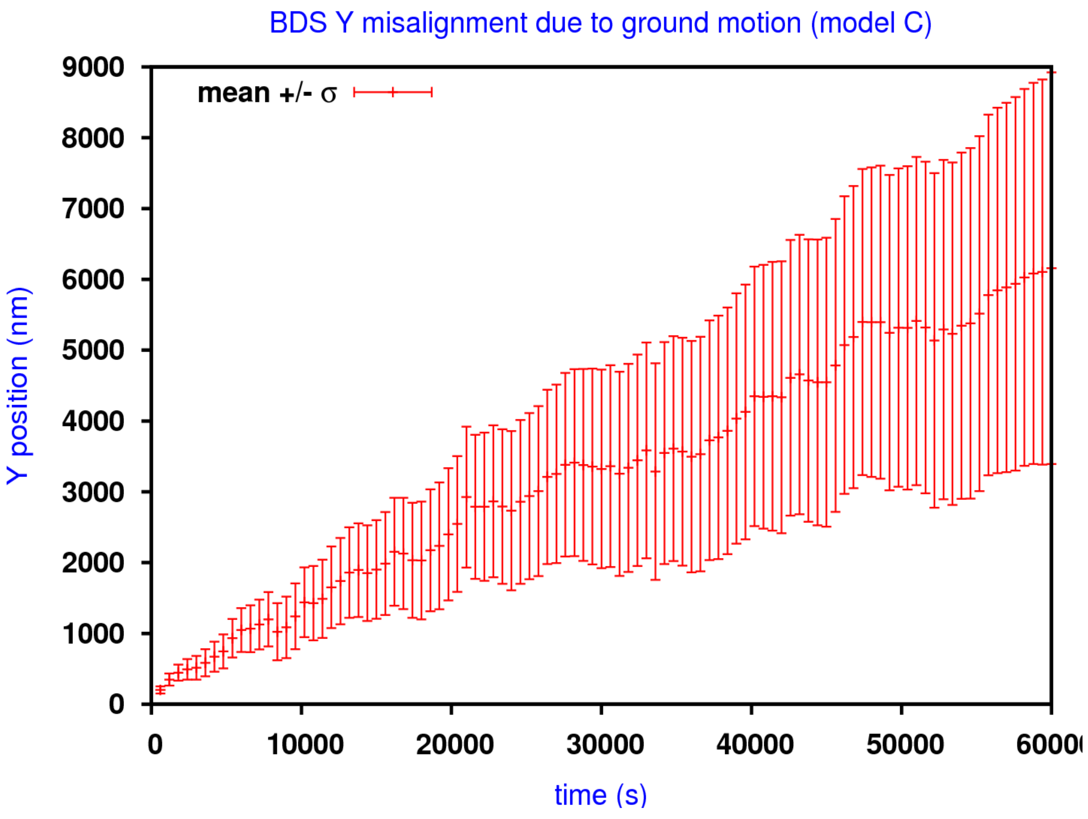


train-train 5 Hz

- Original paper applied 1-D transform for y-offsets
- Ideally we want 2-D x/y displacements and probably element roll
- 20 um displacement over z=20 m and 1 month!

Ground motion BDS misalignment

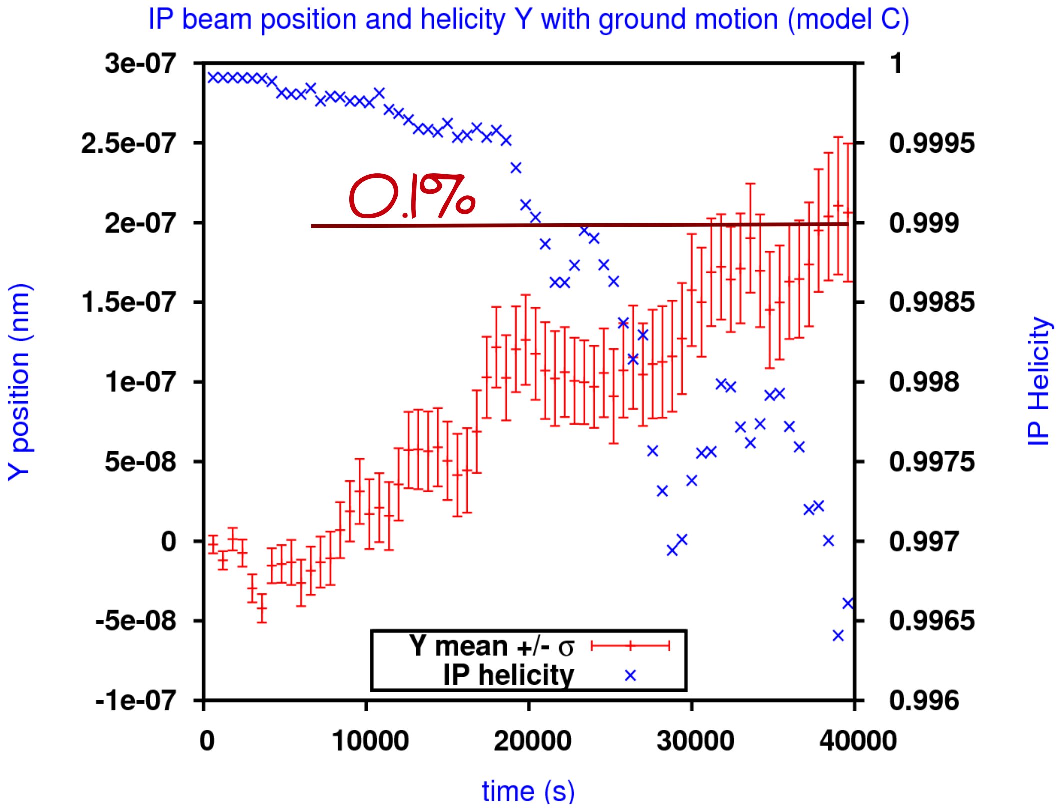




Model:

- Initially aligned, then z-correlated misalignments over time steps
- After many time steps, mean and standard deviation of misalignment grows due to random walk
- On the time scale of a day misalignment grows to the point where BDS depolarisation may be a problem (0.1%)

Ground motion depolarization

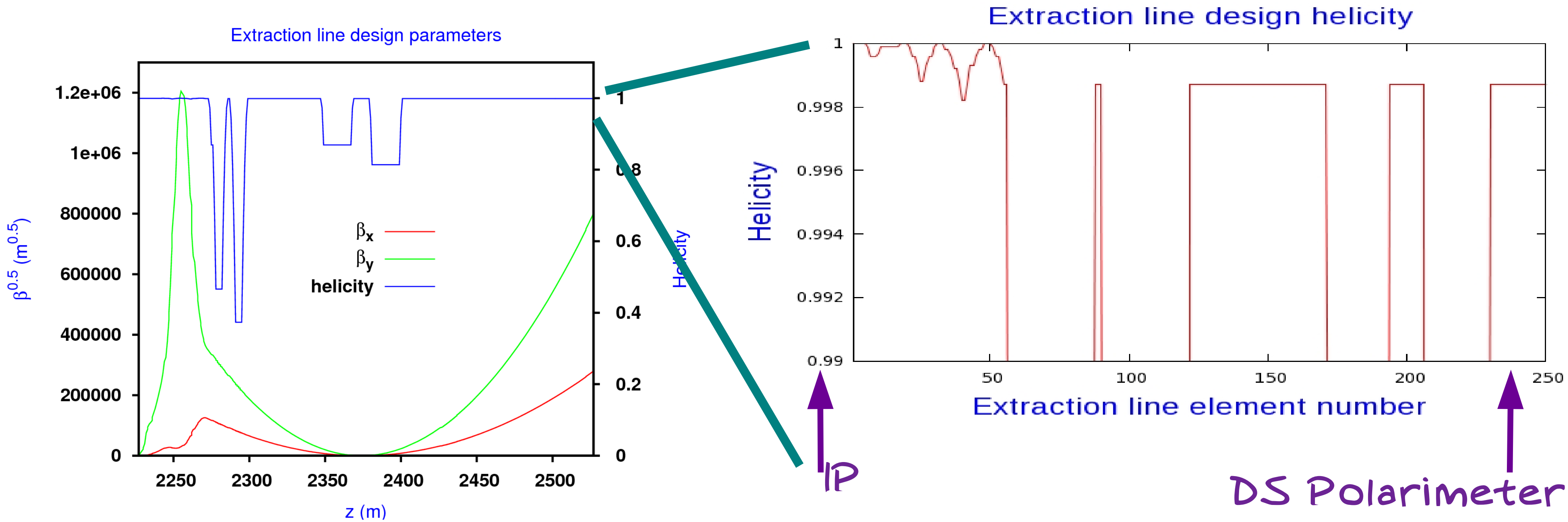


Model:

- Analysis based on initially ideal bunch of 50,000 macroparticles
- Ground motion in linac and orbit correction but assume no depolarization
- Apply realistic ground motion (model C) to BDS
- Examine beam y-profile and helicity at IP

- Within half a day depolarisation reaches its budget limit
- However – final focus magnets stabilised to nm level
  - effect of orbit correction on depolarisation
  - effect of crab cavity on polarisation

Extraction Line



- Extraction line lattice accounts for crossing angle
- Need to include a realistic element for the crab cavity is in the lattice as a drift, need to put in a realistic element
- Depolarization can be sensitive to beam offsets – beam beam kick at IP so look for correlations
- Machine parameters still in flux, polarimeter chicane to have 6 magnets

Integrated Studies (BDS, polarimeter, ExtractionLine and IP) ongoing!

IP depolarization

There is depolarization (spin flip) due to the QED process of Beamsstrahlung, given by the Sokolov-Ternov equation

$$\frac{dW}{d\omega_f} = \frac{\alpha m}{\sqrt{3}\pi\gamma^2}\int_z^\infty K_{5/3}(z)\,dz + \frac{y^2}{1-y}K_{2/3}(z)\ ,\ z\propto\omega_f(1-\cos\theta_f)$$

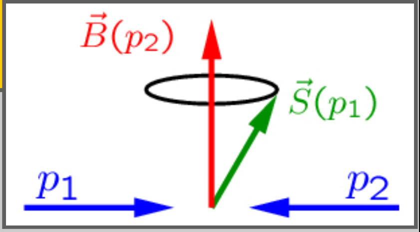
But calculation assumes that the fermion momentum is classical and that all particles colinear

The fermion spin can also precess in the bunch fields. Equation of motion of the spin given by the T-BMT equation

$$\frac{d\vec{S}}{dt} = -\frac{e}{m\gamma}\left[(\gamma a+1)\vec{B}_T+(a+1)\vec{B}_L-\gamma\left(a+\frac{1}{\gamma+1}\right)\frac{1}{c^2}\vec{v}\times\vec{E}\right]\times\vec{S}$$

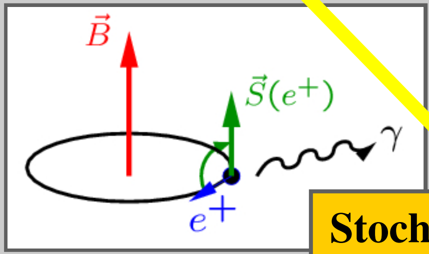
At the IP, the anomalous magnetic moment subject to radiative corrections in the presence of the bunch field

Classical spin precession in inhomogeneous external fields: T-BMT equation.



Depol sims with CLIC parameters (I Bailey) change in polarization vector magnitude

	CLIC-G	ILC nom	ILC (80/30%)
T-BMT	0.10%	0.17%	0.14%
Beamstr.	3.40%	0.05%	0.03%
incoherent	0.06%	0.00%	0.00%
coherent	1.30%	0.00%	0.00%
total	**4.80%**	**0.22%**	**0.17%**



Stochastic spin diffusion from photon emission: Sokolov-Ternov effect, etc.

Summary & Future work

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(5) Depolarisation at the IP due to ILC, CLIC beam-beam collision is significantly large in the depolarisation budget. The quantum spin flip process is also significantly large

(6) for a precision study include higher order QED corrections and use solutions of the Dirac equation in the bunch fields. Cross-check with known Anomalous mag moment in magnetic field