Polarimetry at CLIC (ILC)

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DESY FLC Polarimetry group

(P. Schuler, K.Moffeit – reference work)

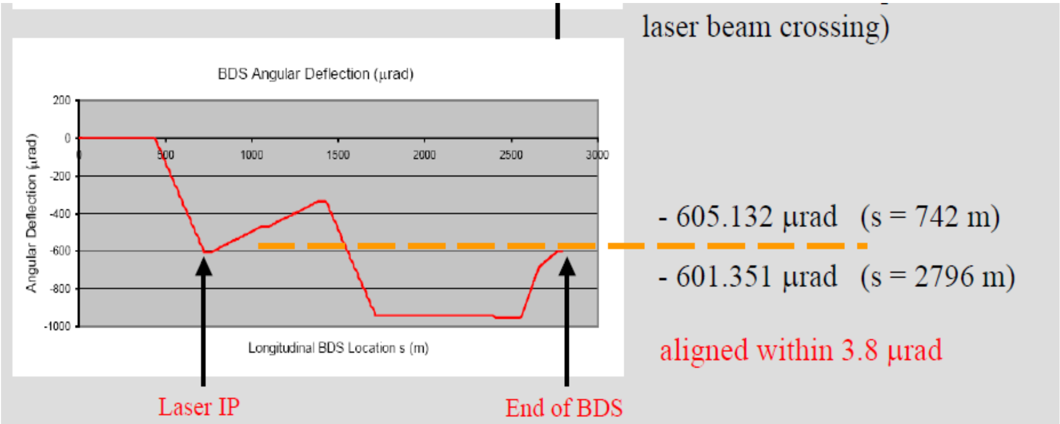
- Requirements on polarimetry
- Cherenkov detector development and ELSA test beam studies
- BDS spin tracking studies wrt ground motion using BMAD
- IP depolarization due to beam-beam interaction

CLIC polarimetry issues/requirements

Starting point is P.Schuler's talk from last years CLIC workshop, K. Moffeit's talk from LC Workshop of the Americas

(1) Physics requirement's (for ILC (assuming similar requirements for CLIC requires polarimetry precision $\delta P/P \le 0.25\%$

Systematic Uncertainty	$\delta P/P$
Detector Analysing power	0.1 - 0.2%
Detector linearity	0.1%
Total	≤ 0.25%



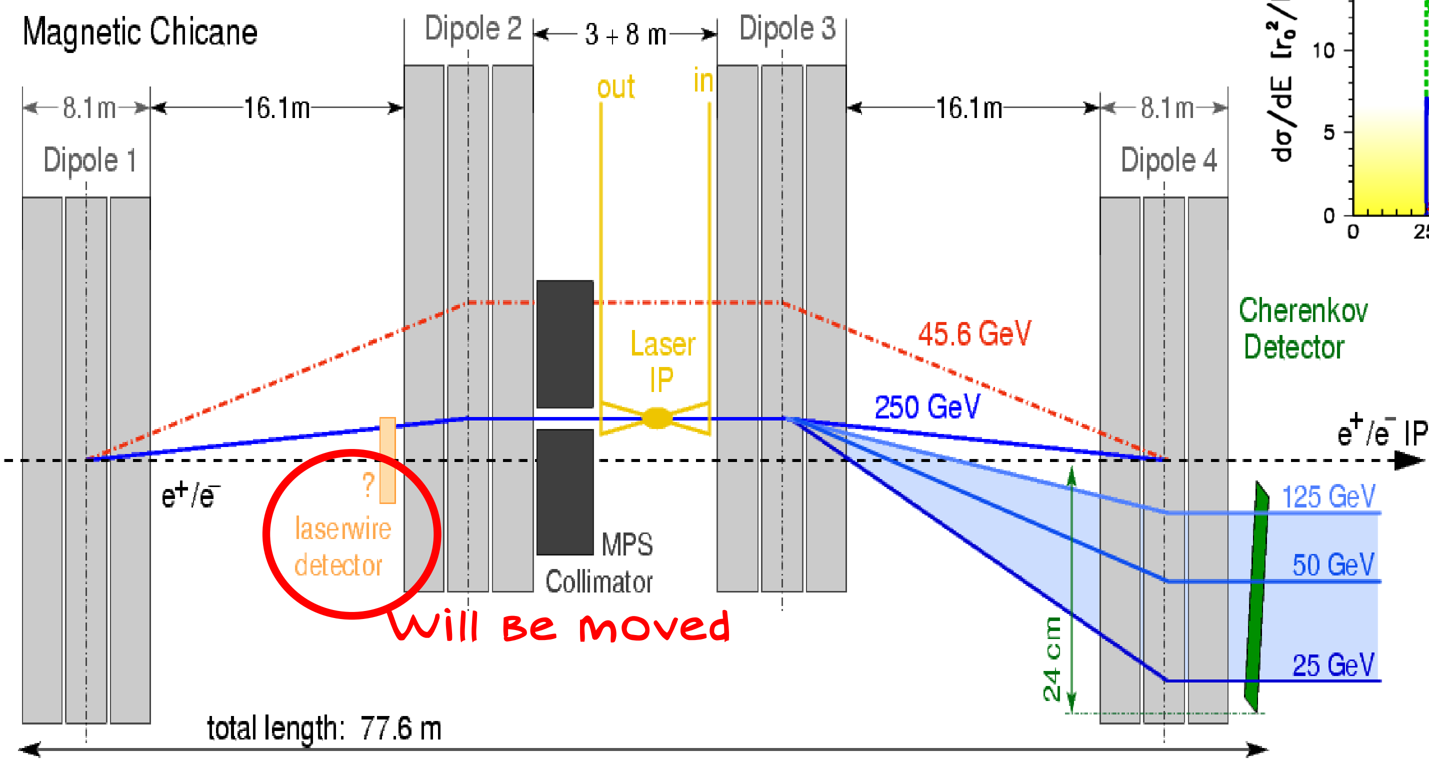
(2) Location for Upstream polarimeter – at 742m from the start of the BDS

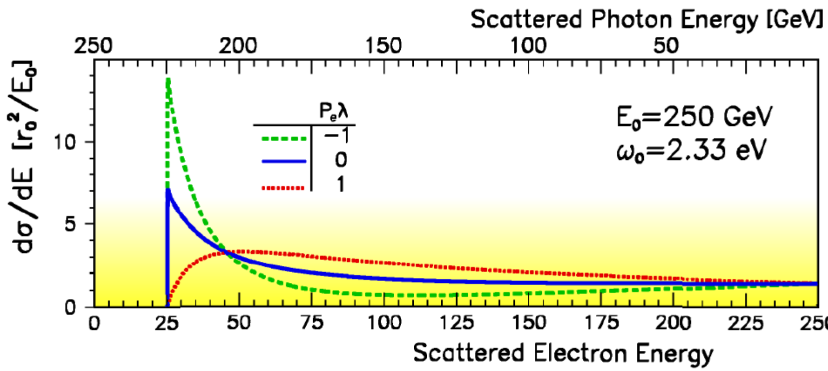
(3) Statistical uncertainty:

BDS: depolarisation from random spin precession due to ground motion – spin tracking studies needed

IP: significant depolarization due to beam-beam effects... **especially** at CLIC

ILC upstream polarimetry scheme



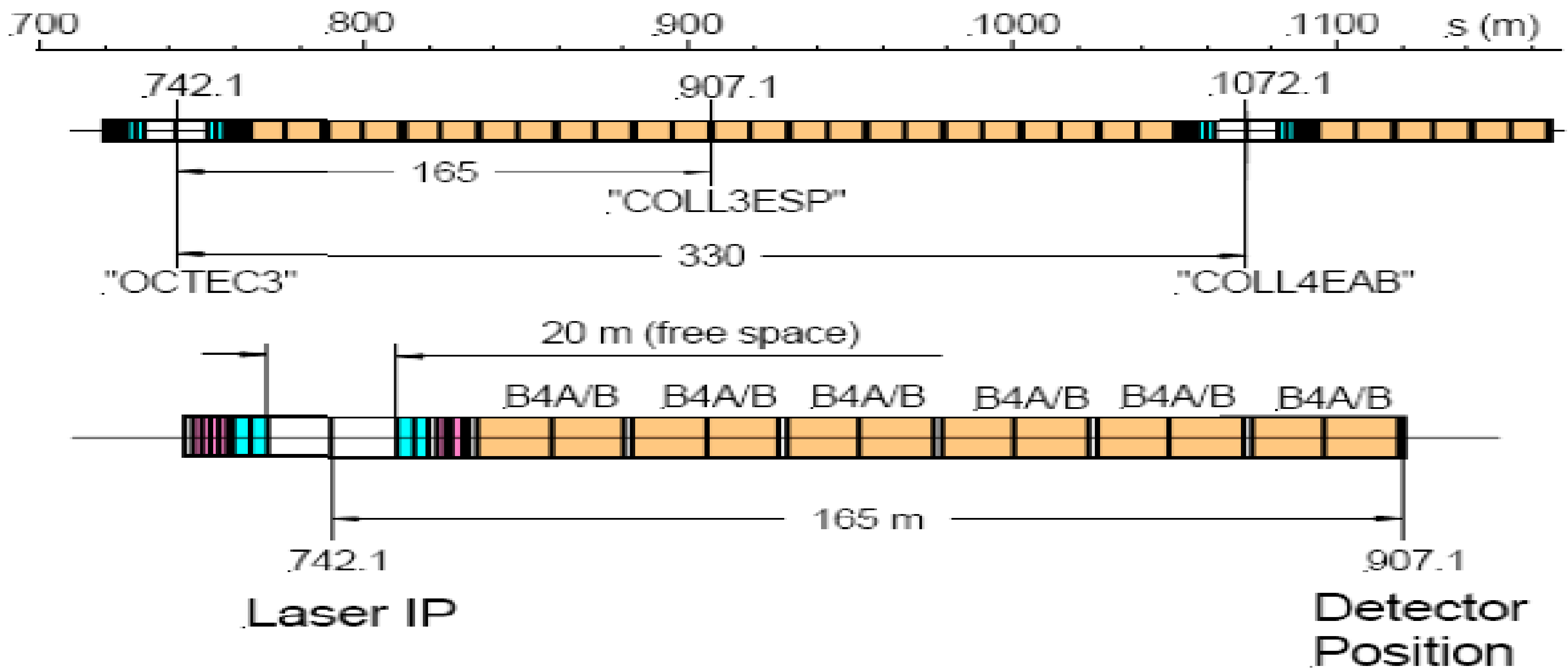


$$\mathcal{A} = \left.\frac{d\sigma^- - d\sigma^+}{d\sigma^- + d\sigma^+}\right|_{P(e)=1}$$

$$P = \frac{\mathcal{A}}{A_{obs}}$$

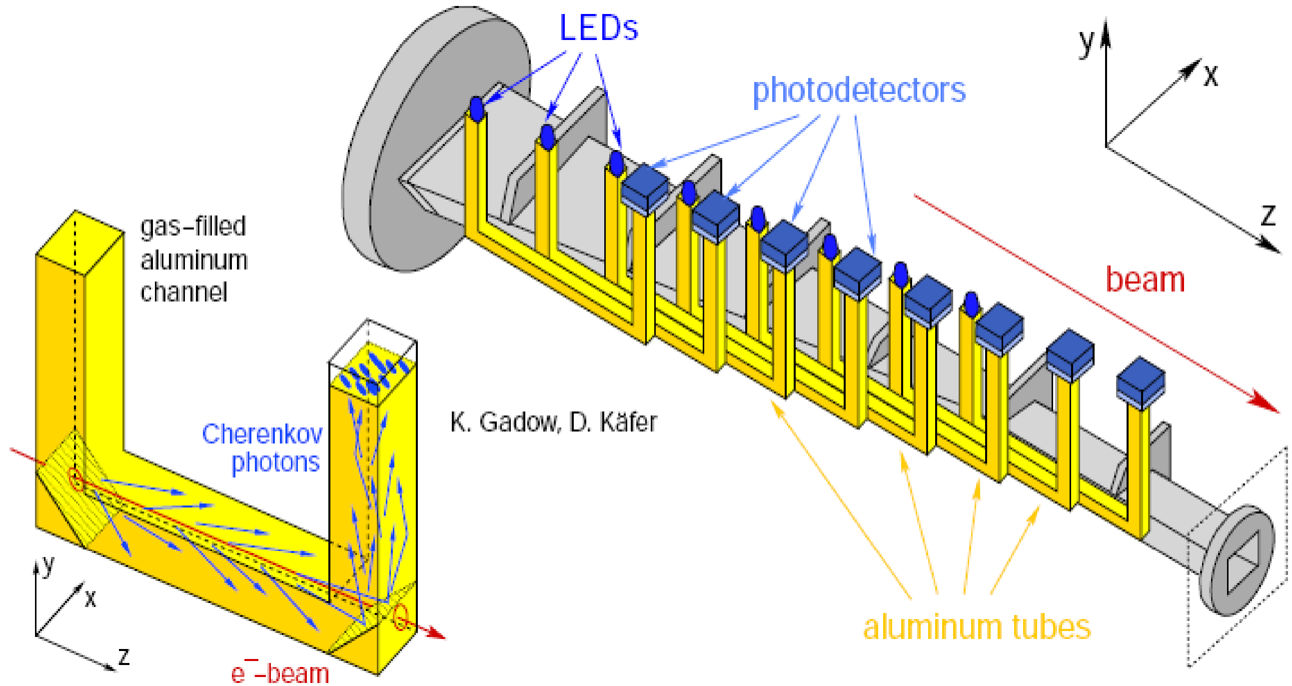
- Laser interaction with polarised beam, to produce a Compton edge (energy) of scattered electrons
- Chicane translates energy spread into spatial spread
- Laser helicity flipped pulse-pulse to obtain analysing power
- Laserwire and polarimeter need to be separated

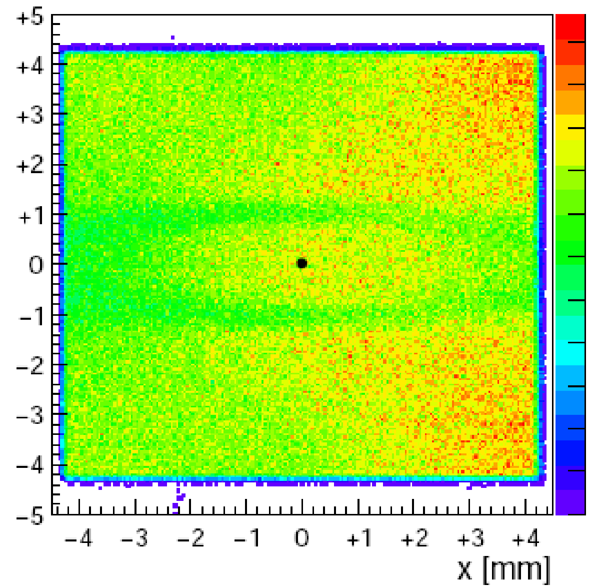
CLIC (possible) upstream location details



- Spin precession match with IP and sufficient space for laser collision at location z=742m
- Dipoles must have sufficient aperture to allow scattered electrons through
- Detector at z=907m
- Detailed studies needed

Cherenkov detector model

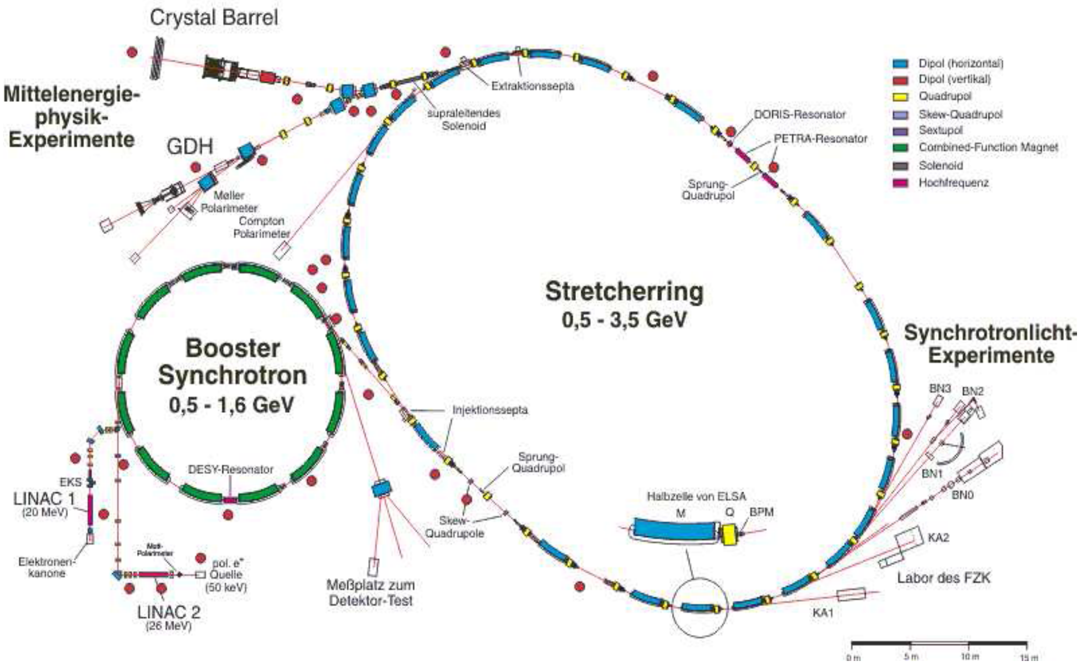


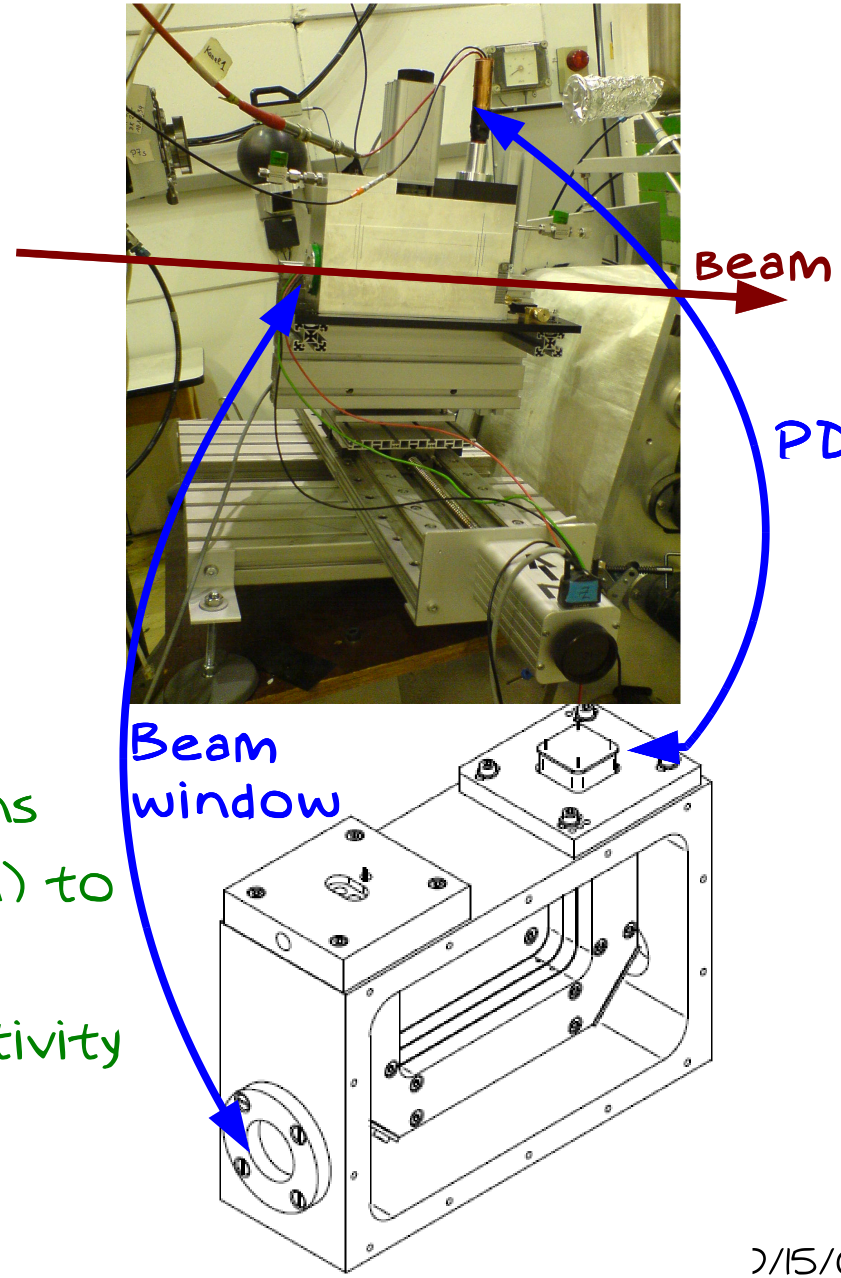


- Required detector coverage needs up to 18, 1cm wide channels
- Gas and light tight. Cherenkov gas is C_4F_{10} (inert, n~1, high Cerenkov threshold of 10 MeV)
- Channel arms rotated out of the Beamstrahlung plane
- LED's provide quick inter-train calibration

- channel wall reflectivity can vary
- Each channel has an inate light distribution
- This has to be calibrated in situ

Detector Prototype and ELSA testBeam



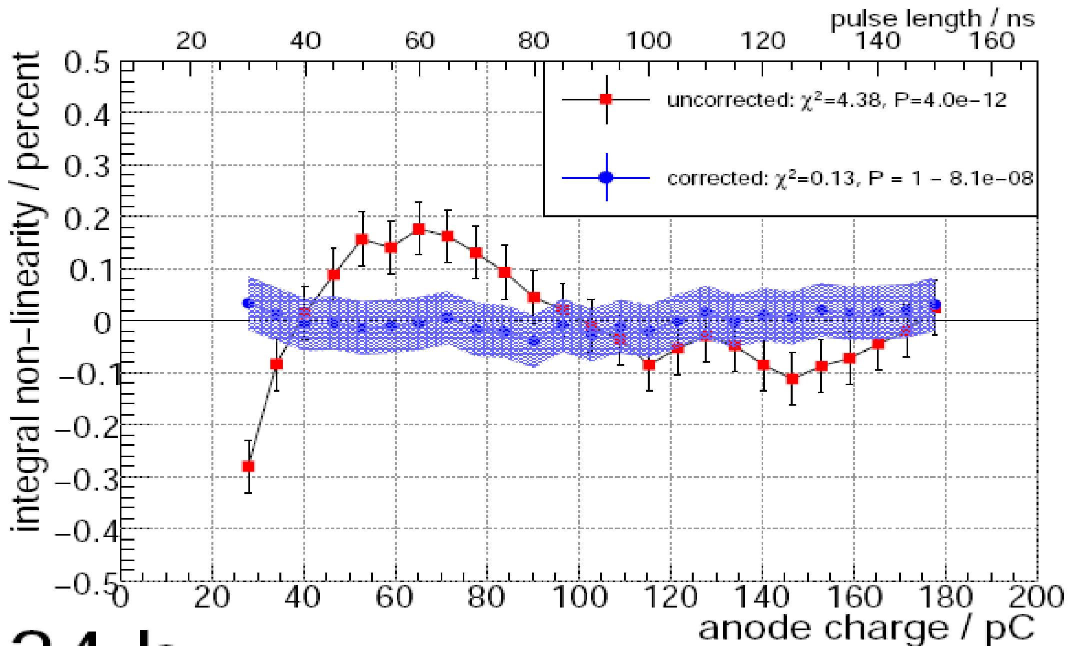


- DESY TB Mar09, ELSA May09 (Dec09)
- ELSA provides 2 GeV unpolarised electrons at rates comparable (~300 per 548ns turn) to expected ILC Compton scattered electrons
- Diamond cut aluminium to maximise reflectivity
- 2 channels only to study crosstalk, linearity with beam current and analysing power

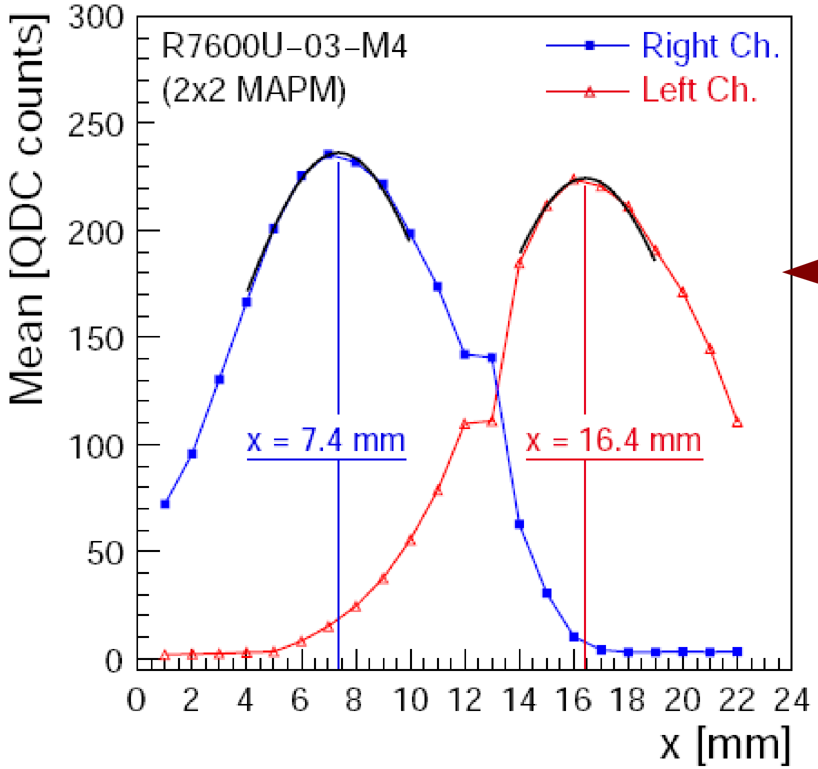
Some testbeam results

Photodector linearity

- Measure integral non-linearity wit increasing LED charge and correct.
- After 24 hours correction is still within 0.1%



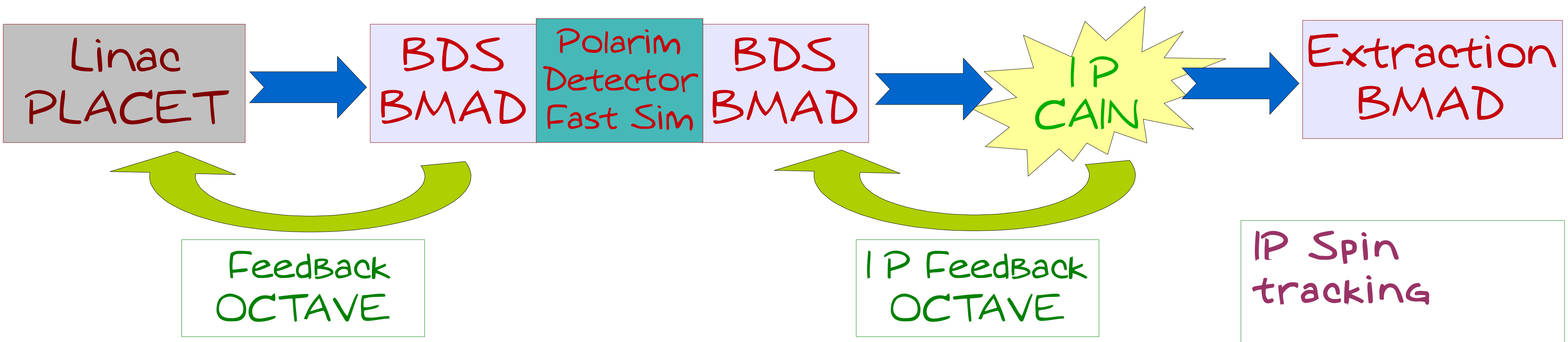
24 h



Channel position scans

- After alignment procedures, the beam is scanned across the two channels
- The peak maxima and widths should be the same and the peak positions reflect the real channel separation (8.8 mm)

Spin tracking Simulation scheme



IP Spin tracking

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

FEEDBACK LOOPS

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

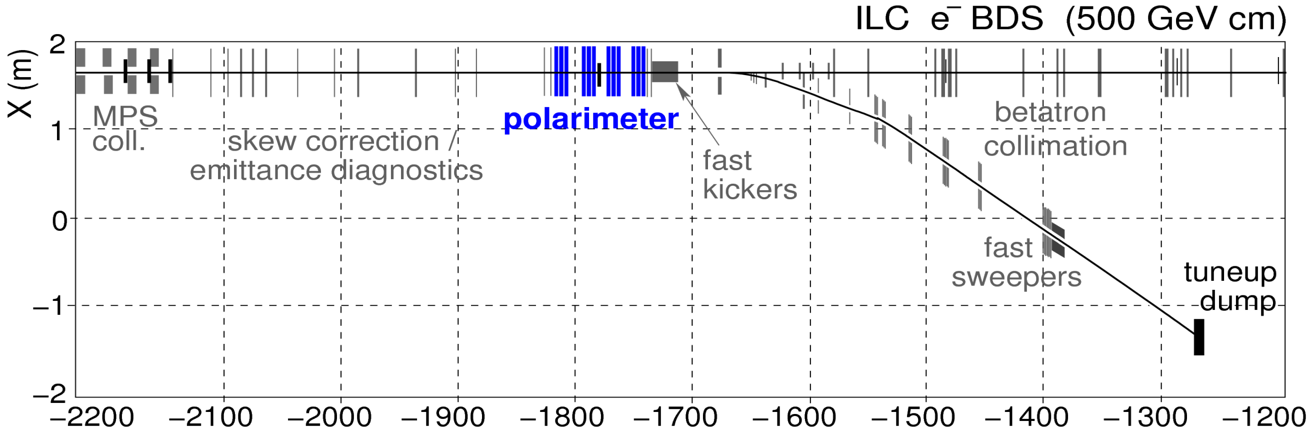
Placet sim of linac

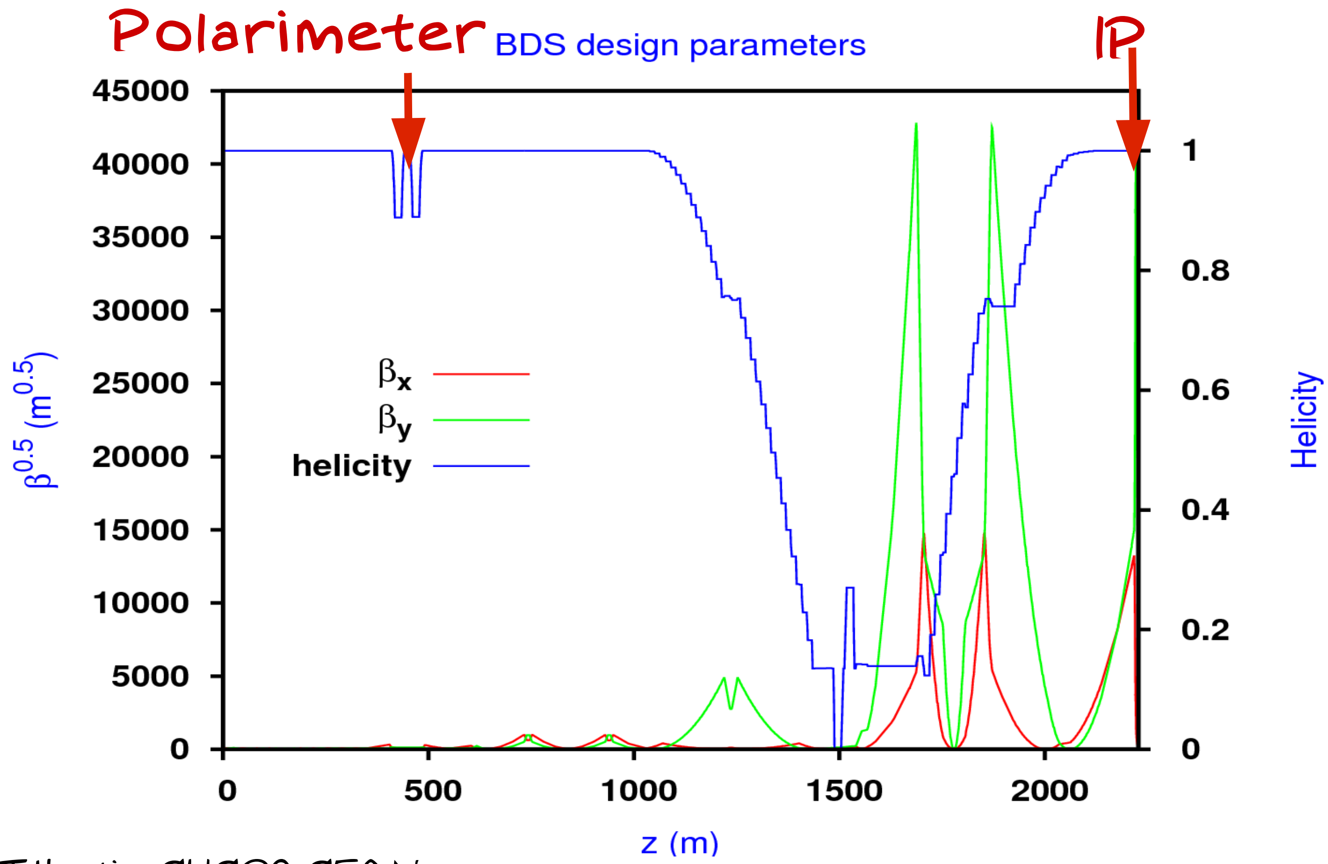
- 1 micron random displacement
- 1:1 correction
- Dispersion free steering
- Deliver multiple Bunch trains of 300 Bunches

BMAD sim of BDS and Extraction

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

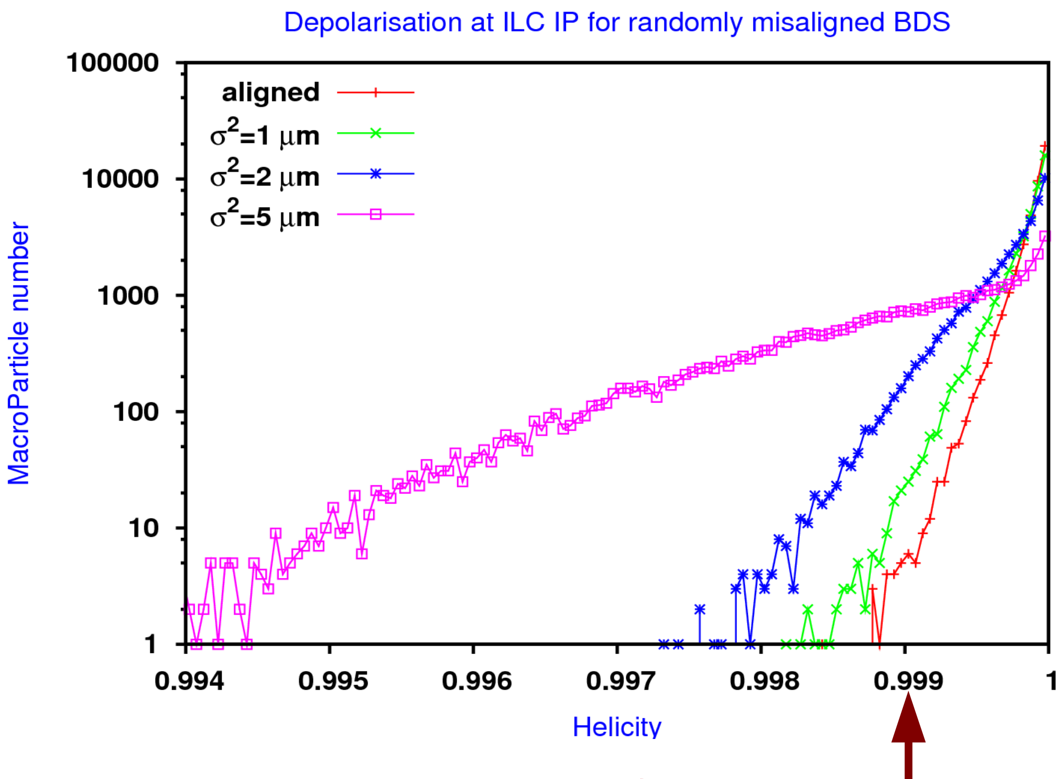
ILC polarimeter and BDS spin tracking





- 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 with random misalignments

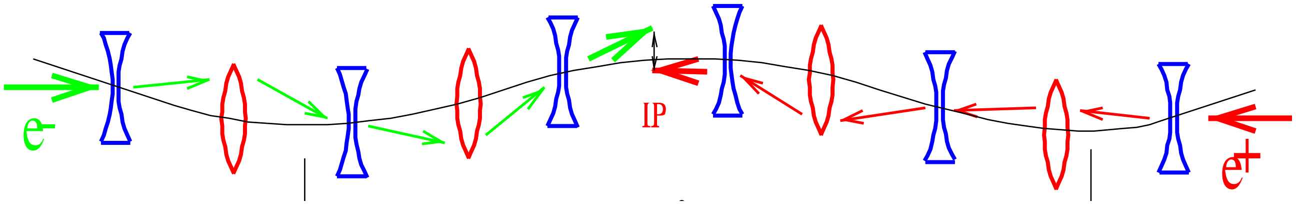


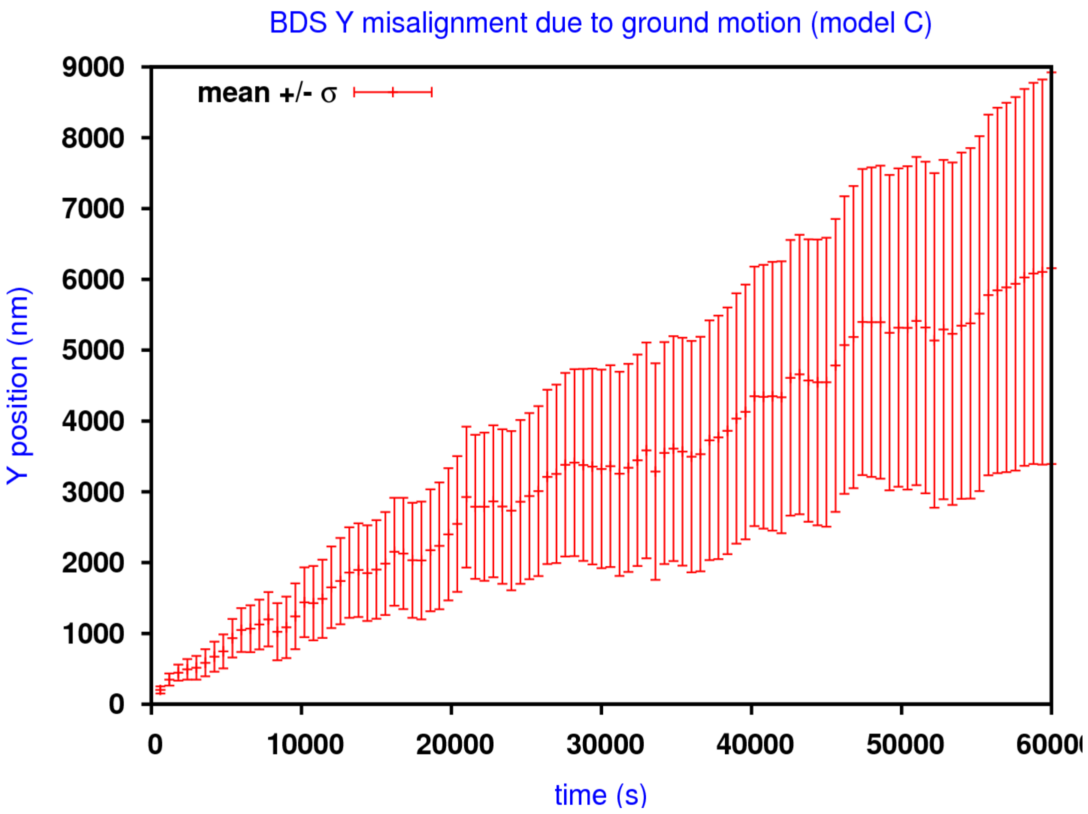
0.1% Depolarization

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

- To do:
  - Make(y) misalignments due to expected ground motion
  - Include fast simulation of upstream polarimeter
  - Examine polarization dependence an end-of-linac feedback
  - Track in the extraction line to downstream polarimeter

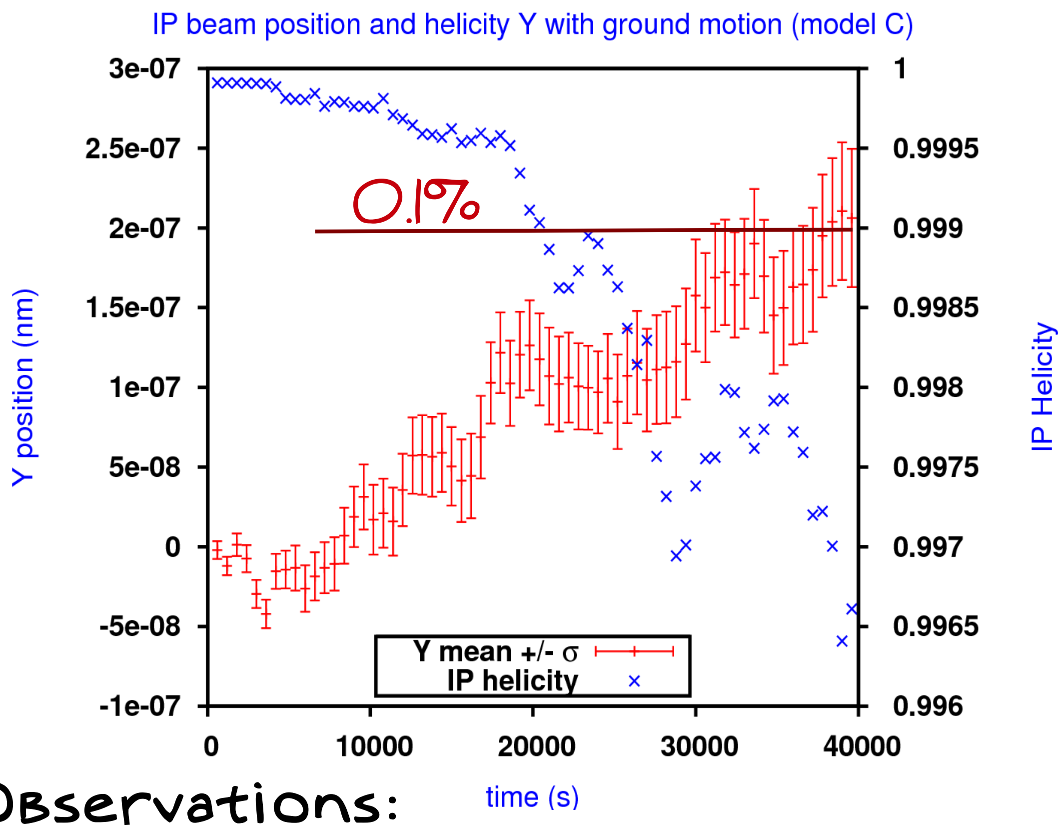
Ground motion BDS misalignment





- Use model C ground motion
- 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

Observations:

- Within half a day depolarisation reaches its budget limit
- Look for correlations – final focus magnets stabilised to nm level

In progress: orbit correction to recover polarisation!

IP depolarization

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

$$\frac{dW}{d\omega_f} = \frac{\alpha m}{\sqrt{3}\pi\gamma^2} \int_z^\infty K_{5/3}(z)\,dz + \frac{y^2}{1-y} K_{2/3}(z) \quad where \; z = \frac{2}{3\Upsilon}\frac{y}{y-1} \;, \quad y = \frac{\omega_f}{\epsilon_i}$$

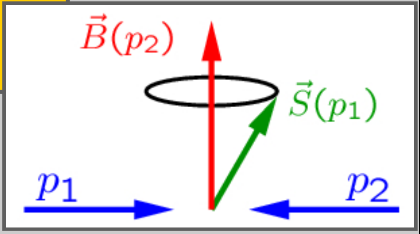
But calculation assumes that the fermion momentum is classical and that all particles colinear

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

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

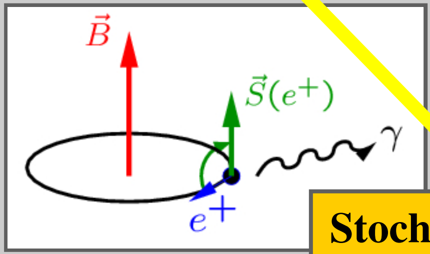
At the IP, the anomalous magnetic moment subject to radiative corrections in the presence of the bunch field

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



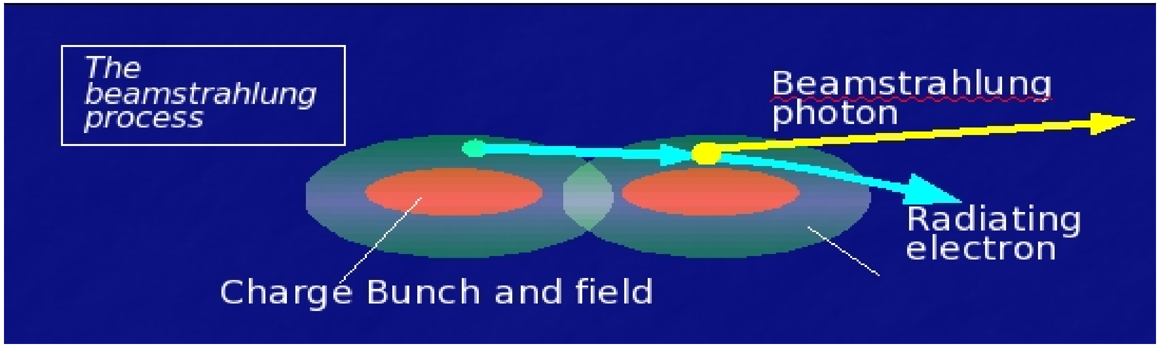
Depol sims with CLIC parameters (I Bailey) change in polarization vector magnitude

	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.

Higher order Beamstrahlung corrections



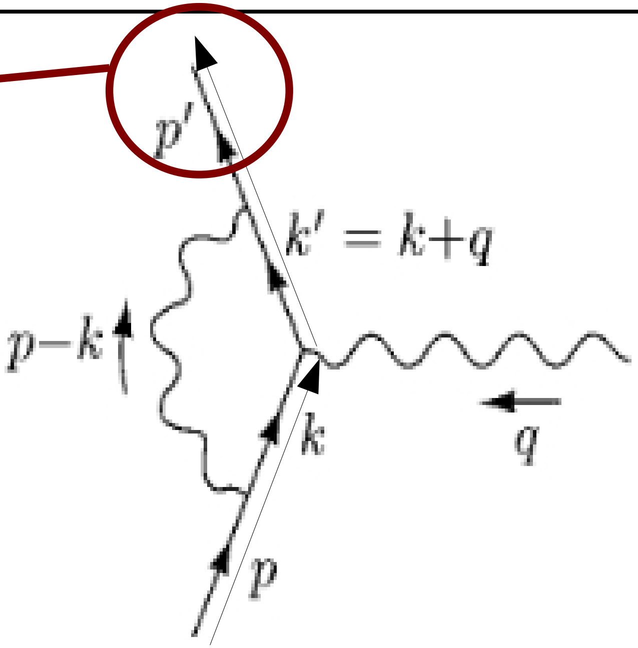
Bunch fields much stronger than magnetic element fields

Intensity parameter: $\Upsilon = \frac{ea\omega}{m^3}$

$\Upsilon \approx 0.1, 1$ For ILC,CLIC

Whenever intensity parameter approaches one the Born approximation is not valid and we must perform calculation in the Furry Picture →Sokolov-Ternov equation. **RADIATIVE CORRECTIONS NEEDED**

Double lines in Feynman diagram indicate solutions of the Dirac Equation in the Bunch field



Calculation complicated! But can check with known results for the anomalous mag moment in a magnetic field

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- 16 theory, simulation and experimental talks
- Proceedings in progress
- Theory reviewed Baier-Katkov and Nikishov-Ritus methods
- Current experiment with crystals at CERN

Proceedings available in the next few months

Summary & Future work

(1) We want to understand all sources of depolarization between upstream and downstream polarimeters, so look in BDS, IP and Extraction line

(2) For the ILC, the upstream polarimeter requires its own chicane. For CLIC a site at 742m in the BDS has been identified – detailed studies needed

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

(7) 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