CLIC Undulator Option for Polarised Positrons

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Overview

- Motivation for polarised positrons
- Challenges from depolarisation
- Undulator-scheme technology status
  - (ILC context)
- Global machine implications
- Proposed CLIC studies

Motivation for Polarised Positrons

Extract from "Polarized positrons and electrons at the linear collider",

G. Moortgat-Pick et al, Physics Reports 460 (2008) 131243.

Gain shown is due to (Pe-, Pe+) =

(80%, 60%) compared with

(80%, 0%).

Case	Effects	Gain& Requirement
SM:		
top threshold	Electroweak coupling measurement	factor 3
$t\bar{q}$	Limits for FCN top couplings improved	factor 1.8
CPV in $t\bar{t}$	Azimuthal CP-odd asymmetries give access to S- and T-currents up to 10 TeV	$P^T_{e^-} P^T_{e^+}$ required
W^+W^-	Enhancement of $\frac{S}{B}$, $\frac{S}{\sqrt{B}}$	up to a factor 2
	TGC: error reduction of $\Delta\kappa_\gamma$, $\Delta\lambda_\gamma$, $\Delta\kappa_Z$, $\Delta\lambda_Z$	factor 1.8
	Specific TGC $\tilde{h}_+ = \mathrm{Im}(g_1^R + \kappa^R)/\sqrt{2}$	$P^T_{e^-} P^T_{e^+}$ required
CPV in γZ	Anomalous TGC $\gamma\gamma Z$, γZZ	$P^T_{e^-} P^T_{e^+}$ required
HZ	Separation: $HZ \leftrightarrow H\bar{\nu}\nu$	factor 4 with RL
	Suppression of $B = W^+\ell^-\nu$	factor 1.7
$t\bar{t}H$	Top Yukawa coupling measurement at $\sqrt{s} = 500$ GeV	factor 2.5
SUSY:		
$\tilde{e}^+\tilde{e}^-$	Test of quantum numbers L, R and measurement of $e^\pm$ Yukawa couplings	P_{e^+} required
$\tilde{\mu}\tilde{\mu}$	Enhancement of S/B, $B = WW$ $\Rightarrow m_{\tilde{\mu}_{L,R}}$ in the continuum	factor 5-7
HA, $m_A > 500$ GeV	Access to difficult parameter space	factor 1.6
$\tilde{\chi}^+\tilde{\chi}^-$, $\tilde{\chi}^0\tilde{\chi}^0$	Enhancement of $\frac{S}{B}$, $\frac{S}{\sqrt{B}}$	factor 2–3
	Separation between SUSY models, 'model-independent' parameter determination	
CPV in $\tilde{\chi}^0_i\tilde{\chi}^0_j$	Direct CP-odd observables	$P^T_{e^-} P^T_{e^+}$ required
RPV in $\tilde{\nu}_\tau \to \ell^+\ell^-$	Enhancement of S/B, $S/\sqrt{B}$	factor 10 with LL
	Test of spin quantum number	
ED:		
$G\gamma$	Enhancement of S/B, $B = \gamma\nu\bar{\nu}$,	factor 3
$e^+e^- \to f\bar{f}$	Distinction between ADD and RS models	$P^T_{e^-} P^T_{e^+}$ required
Z′:		
$e^+e^- \to f\bar{f}$	Measurement of Z' couplings	factor 1.5
CI:		
$e^+e- \to q\bar{q}$	Model independent bounds	P_{e^+} required
Precision measurements of the Standard Model at GigaZ:		
Z-pole	Improvement of $\Delta\sin^2\theta_W$	$\sim$ factor 10
	Improvement of Higgs bounds	$\sim$ factor 10
	Constraints on CMSSM parameter space	factor 5
CPV in $Z \to b\bar{b}$	Enhancement of sensitivity	factor 3

Challenges of Depolarisation

HeLiCal collaboration is developing software tools to study evolution of polarisation from source to interaction point in linear colliders and elsewhere.

Generally most interesting spin dynamics effects occur in rings…

However, even in a linear collider, both stochastic spin diffusion through photon emission and classical spin precession in *inhomogeneous* magnetic fields can lead to depolarisation.

$$\delta\theta_{spin} \propto \frac{(g-2)}{2}\gamma\delta\theta_{orbit}$$

1 mrad orbital deflection ⇒ 30° spin precession at 250GeV.

Largest depolarisation effects at ILC / CLIC are expected at the Interaction Points.

Depolarisation at the ILC

- **Damping Rings**
  - **Depolarization (e^-) ~5×10^{-5} %**
  - **Depolarization (e^+) ~1×10^{-3} %**
- **Main linac**
  - **Spin precession ~26°**
  - **Depolarization~5×10^{-7} %**
- **BDS**
  - **Spin precession ~332°**
  - **Depolarization~0.06 %**
- **IP**
  - **Depolarization ~0.2 %**

Challenges of Depolarisation

HeLiCal collaboration is developing software tools to study evolution of polarisation from source to interaction point in linear colliders and elsewhere.

In addition, turn-arounds and spin rotators need careful planning. See talk by K. Moffeit in BDS and MDI working group.

Current simulations predict ~4.8% depolarisation at CLIC-G with large theoretical uncertainties. See talk by A. Hartin in BDS and MDI working group.

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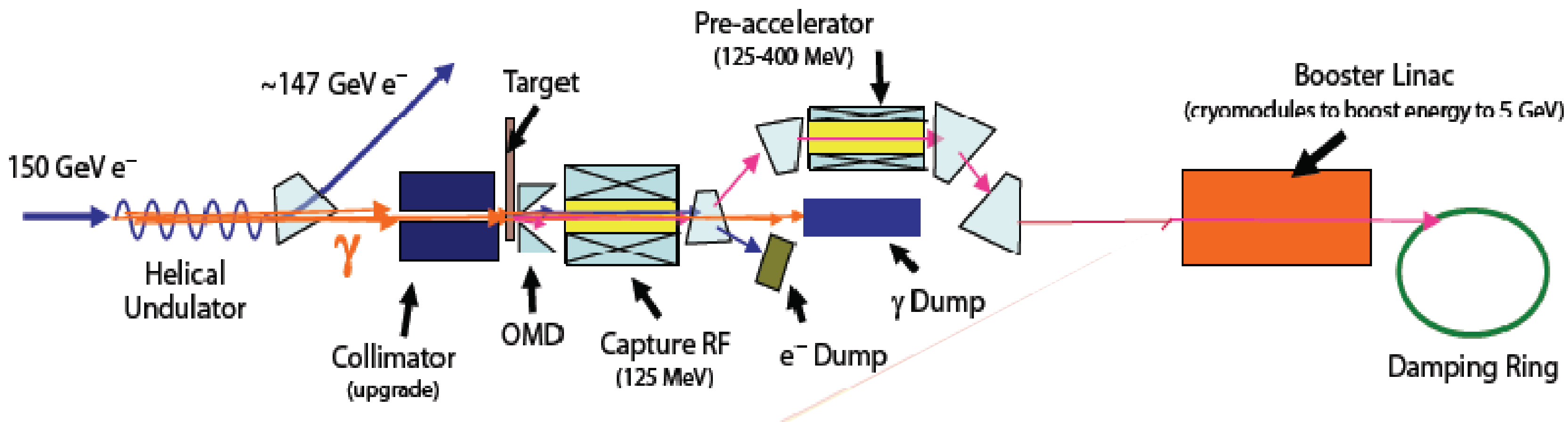
ILC RDR Positron Source Design



- Based on a helical undulator insertion device
- Photons incident on a thin (0.4 rl) Ti6%Al4%V target
- Active (K=0.92, period=1.15 cm, B_0=0.86T) undulator: 147 m
  - Photon beam power: 131 kW
  - Photon energy: ~10 MeV (First harmonic)
  - Beam spot: >1.7 mm rms
  - Net positron polarisation ~30%
- Designed underpinned by E166 experiment

~300γ/e
⇒no stacking

K – "deflection parameter"

$$K = \frac{eB_0}{km_0c}$$

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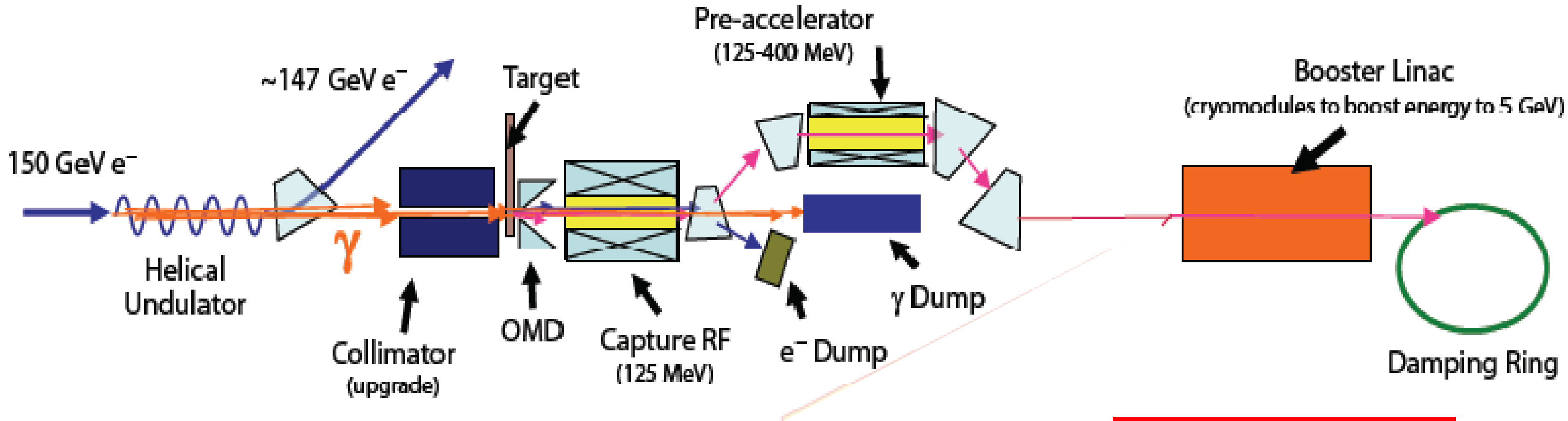

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~0.53T in ANL CLIC design. Increase aperture.

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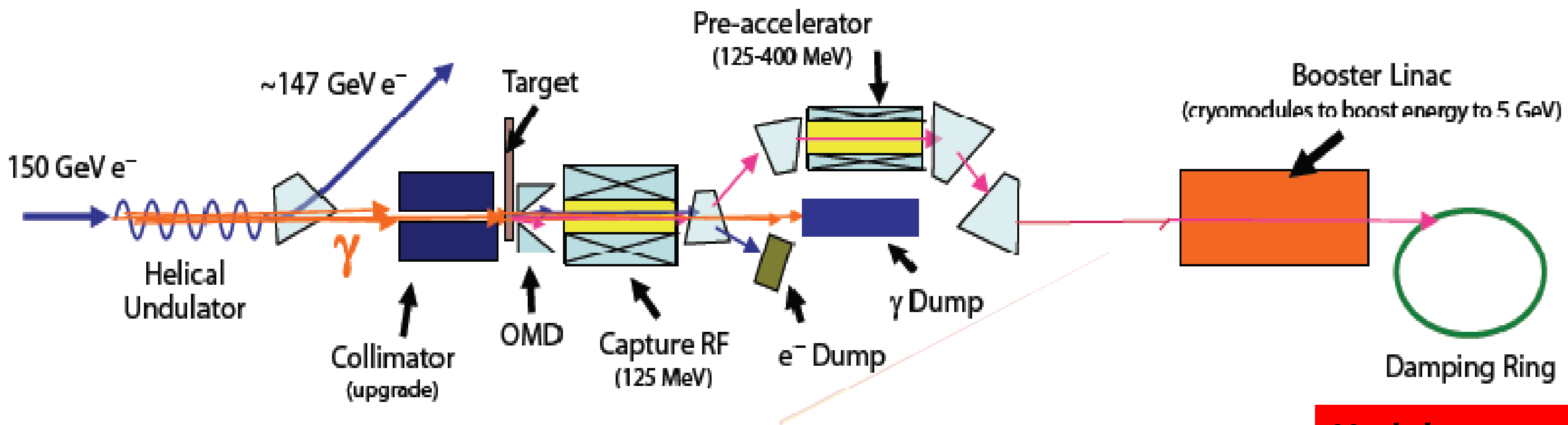

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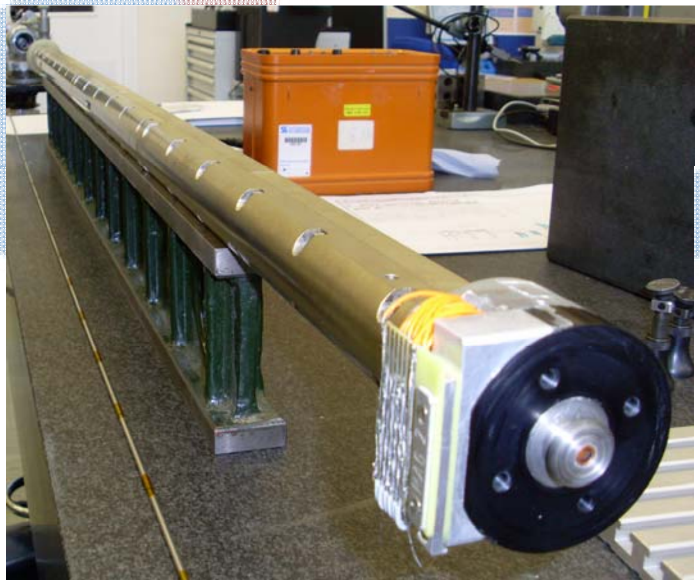
Undulator was choosen for ILC not because of polarisation but because it minimised perceived risk.

K – "deflection parameter"

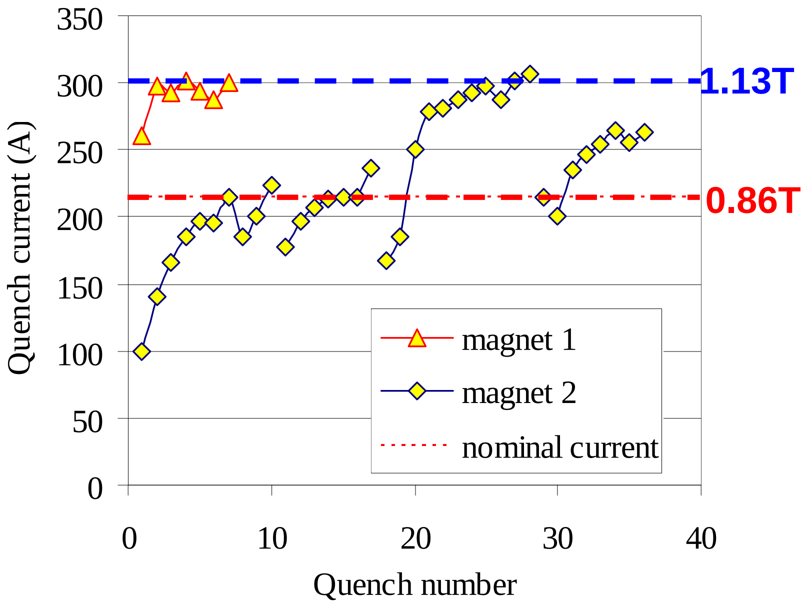
$$K = \frac{eB_0}{km_0c}$$

Technology Status - Undulator

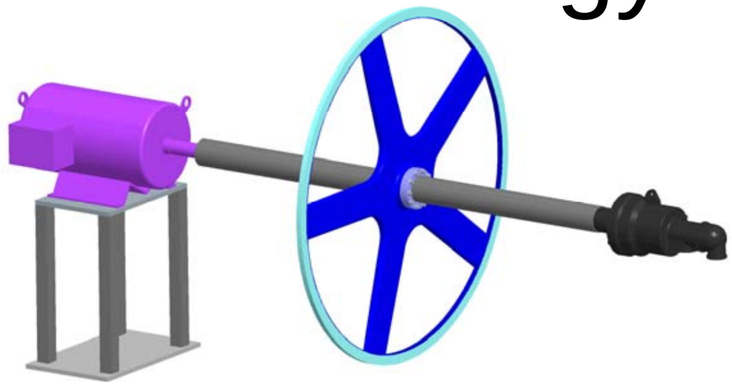
- Short period, high field, only possible with **narrow aperture (5.85mm)**
- Presents challenges:
  - Resistive wall effects
  - Vessel surface roughness effects
  - Synchrotron radiation power problems (desorption)
  - Generating a vacuum with difficult aspect ratio
  - Mechanical tolerances
  - Manufacturing issues



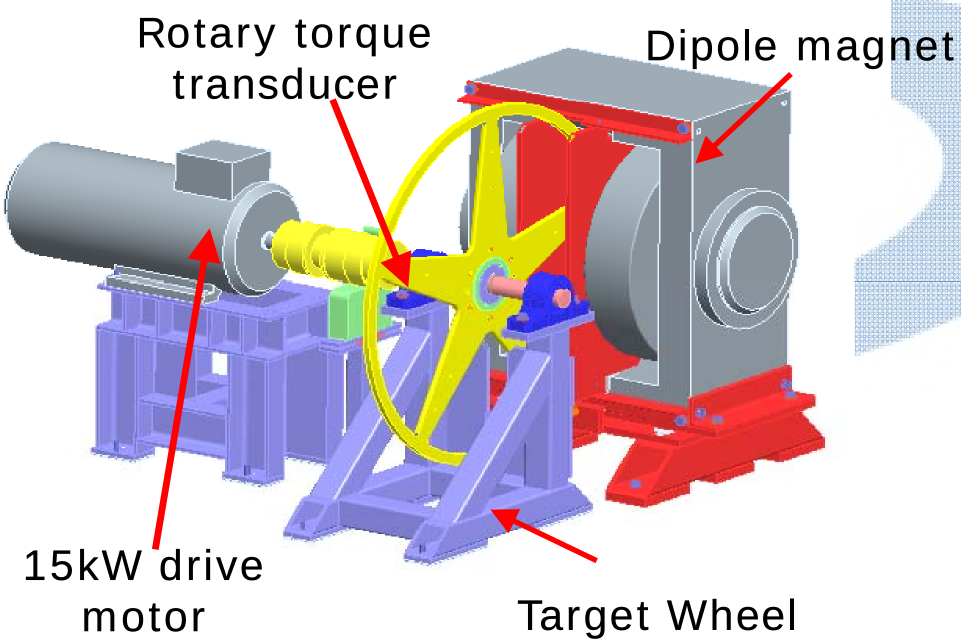
1.75m superconducting undulator at RAL



Technology Status - Target



T. Piggott, LLNL



Prototype at Daresbury Laboratory

- **Wheel rim speed (100m/s) fixed by thermal load (~8% of γ beam power)**
- **Rotation reduces pulse energy density (averaged over beam spot) from ~900 J/g to ~24 J/g**
- **Cooled by internal water-cooling channel**
- **Wheel diameter (~1m) fixed by radiation damage and capture optics**
- **Materials fixed by thermal and mechanical properties and pair-production cross-section (Ti6%Al4%V)**
- **Wheel geometry (~30mm radial width) constrained by eddy currents.**
- **20cm between target and rf cavity.**
- **Axial thickness ~0.4 radiation lengths.**

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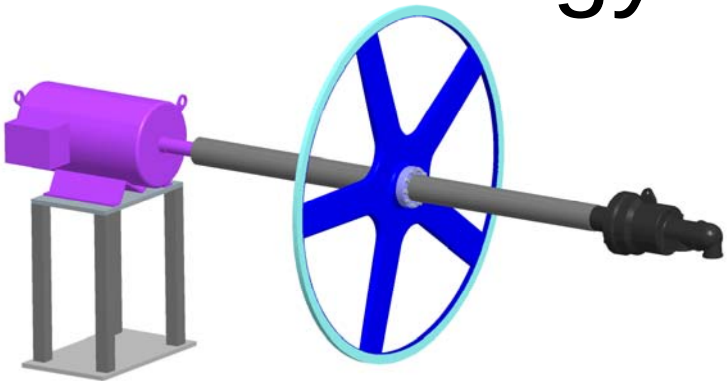

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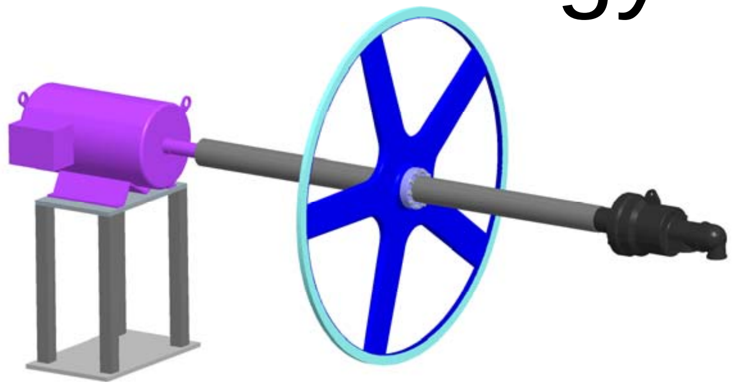

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Global considerations

- Coupled beam operation
  - Possible need for commissioning source.
- Electron beam emittance dilution
  - Wakefield effects for ILC shown to be small.
- Electron beam depolarisation
  - Analytical models show depolarisation to be negligible
- Timing constraints
  - Damping ring fill patterns
- Increased length of e^- tunnel (1.25 km for ILC RDR)
  - Cost implication
- Z^0 detector calibration
  - Constrains undulator position

Proposed CLIC Studies at CI

- Undulator-based source
  - Develop Geant4 model of collimator, target, capture optics, and capture rf assembly.
  - Optimise parameters (e.g. undulator position) wrt yield, polarisation and cost. (Coordination needed with ANL).
  - Consider timing constraints issues and upgrade paths.
  - Consider electron beam quality issues.
  - Consider optimal target technology (thermal load, shock waves, activation).
- Compton source
  - Extend Geant4 model to Compton source. (Coordinate with LAL)
  - Stacking simulations? Desirable, but effort not yet identified.
- Lithium lens capture optics
  - Evaluate suitability for Undulator and Compton schemes at CLIC. (Wide coordination needed.)
- Electron source
  - Tracking studies. (Coordinate with JLAB)

Conclusion

- Positron polarisation is highly desirable
  - Not necessarily only reason to choose undulator
- Polarisation has to be “designed-in” globally.
- Undulator-based positron source technology in mature state.
- Overall impact on machine operation needs to be re-evaluated for CLIC (c.f. ILC)
- Much scope for optimisation studies
  - Coordination required