A Helical Undulator for the Production of Polarised Positrons

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Contents

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- Polarised Positron Production
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TESLA

- T eV
- Energy
- Super-conducting
- Linear
- Accelerator
- 250 GeV (per beam) e+ e- Linear Collider
TESLA Layout

- Injector system
  - Particles created initial acceleration
- Damping Rings
  - Beam size is reduced by emitting of synchrotron radiation
- Very long LINAC to accelerate particles to 250 GeV
- Interaction Point
TESLA Layout
Efficient positron production is a limiting factor on the performance of a LC.

The present system involves:
- An undulator to produce radiation
- A target where radiation creates electron positron pairs
- Positrons “captured” and accelerated
Positron Production Schematic

250 GeV e\textsuperscript{-} Beam
Polarised Positrons

- A ‘Helical Undulator’ would provide **Polarised \(\gamma\) rays**,
- These could produce **Polarised Positrons**

**Helical Field** - Rotating dipole field in the transverse planes

\(e^-\) beam follows a helical path

Circularly Polarised Photons
Required Magnetic Field

Required B Field to Produce 20 MeV Photons

On Axis B Field (T)

Undulator Period (cm)
Permanent Magnet Undulator Design

- “Halbach” undulator (Klaus Halbach NIM Vol. 187, No1)

- PPM blocks create **Dipole Field**

- Rotate many rings to create **Helical Field**
Super- Conducting Design

- Super-Conducting Wires
- 2 wires wrapped around vacuum vessel

Undulator Period, $u$

Current, $i$

Current, $-i$

Helix Diameter
3D-Modelling

- Based on meeting the required on-axis field looked at
  - Different Period Lengths
  - Different Helix Bores
  - Different Wire Dimensions
- Calculated conductor margins for each case
  - The assumptions for calculating the conductor margins were
    - Wire packing factor of 0.74
    - Normal:SC ratio of 1:1
    - Super-Conductor is NbTi
    - Temperature is nominal 4.2K
3D - Model Used

Period

+1200 A/mm²

-1200 A/mm²

R=2mm

dZ=4mm

dR=4mm

01/07/03
Duncan Scott: Super-Conducting Workshop
Picture shows peak field plots in the windings for the FEA model.
A 12mm period would work, however

- Former has to be made & wires wrapped around it
- Space is needed for the e⁻ beam
### Results - Changing Bore

<table>
<thead>
<tr>
<th>Bore (mm)</th>
<th>Pitch (mm)</th>
<th>Winding width (mm)</th>
<th>Curd (A/mm²)</th>
<th>B axis (T)</th>
<th>B peak (T)</th>
<th>Short sample %</th>
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</table>

- A 14mm period is recommended
  - Wires will wrap around it
  - 4mm beam stay clear for the electron beam
Qualitative Effects of Iron

- Iron can be added in places to improve the field strength

- Iron Sleeve Increases on-axis Field strength and is fairly easy to do
Qualitative Effects of Iron

- Iron sleeve and iron between windings creates the best result
- Attaching iron to the vacuum vessel would be difficult
Qualitative Effects of Iron

- For a completely iron former and iron sleeve the field is less than the other two cases - but still better than no iron

Electron Beam
Power Dissipated - SR

- Power dissipated as a function of the distance through the undulator
  - far field approximation used
  - 4mm beam stay clear assumed
Vacuum System

- TESLA Requirements are $10^{-8}$ mbar (CO Equivalent)
  - Single-pass Machine
- This is equivalent to photon flux of $\sim 10^{17}$ photons s$^{-1}$ m$^{-1}$
- Super-Conducting Magnet
  - Power levels indicate flux is less than this amount
- Pure Permanent Magnet
  - NEG Coating will be required
  - NEG coating of a 4mm Diameter Pipe has never been achieved
Making the Former

- Prototype former made from cutting grooves into cylinder
Magnet Design Conclusions

- A super-conducting double helix design is recommended with the following properties
  - 14mm period
  - 6mm helix diameter
  - 4mm electron beam stay clear
  - Wires made up of 16 filaments bonded into former
- (A similar result is reached for the PPM “Halbach” design)
Further Work

- Complete magnet design
  - Looking at having iron to help reduce the required current density
- Analyse effects of magnetic field errors
- Build a Prototype
  - Looking to build a short (~20 Period) device - hopefully of both technologies
  - Use a custom probe to measure magnetic field
- Use Prototype
  - Test emitted radiation by placing undulator in a test beam, e.g. 4GLS, TTF2
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