Baseline Positron Production and Capture Scheme for CLIC

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Foreword

Positron production requirements

1. High energy $e^-$ beam
2. Radiator to produce $\gamma$: Amorphous, Undulator, Compton scattering, Crystal ....
3. Converter to produce $e^+e^-$ pairs: material with high Z value (W)
   - Conventional scheme single thick target
   - Hybrid scheme crystal plus amorphous targets
4. Matching lens to focus the $e^+$ beam

Outline

• CLIC positron complex
• Channelling effect from a crystal target
• Positrons production using an hybrid source
  Amorphous & Capture studies
• Conclusion
CLIC positron complex

- **CLIC**: Compact Linear Collider
  - J.-P. Delaye’s talk on Friday

- **Need an intense e\(^+\) source @ IP**
  - \#e\(^+\)/bunch : 3.7×10\(^9\)
  - \#bunches/train : 312
  - Repetition : 50 Hz

- **Limitation from the conventional source**
  - Large e\(^+\) emittance values \(\Rightarrow\) transport and damping time
  - Heating and energy deposition density \(\Rightarrow\) melt or breakdown target

- **CLIC e\(^+\) production baseline**

Crystal + Amorphous \(\Rightarrow\) Hybrid Source

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Channelling effect from a crystal target

- A few GeV electron beam aligned to a $<111>$ oriented crystal

- Enhancement of $\gamma$ production w.r.t. to pure Bremsstrahlung process

- Due to energy deposition constraints
  - Thin crystal target
  - Converter downstream the crystal

  - Sweeping off the charged particles between the crystal and the amorphous targets

<table>
<thead>
<tr>
<th>$E_e$ (GeV)</th>
<th>t (mm)</th>
<th>$N_\gamma/N_{e-}$</th>
<th>$&lt;E_\gamma$ (MeV)&gt;</th>
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</thead>
<tbody>
<tr>
<td>10</td>
<td>1.0</td>
<td>22.5</td>
<td>300</td>
</tr>
<tr>
<td>5</td>
<td>1.4</td>
<td>20.0</td>
<td>160</td>
</tr>
<tr>
<td>4</td>
<td>1.5</td>
<td>18.5</td>
<td>130</td>
</tr>
<tr>
<td>3</td>
<td>1.6</td>
<td>15.5</td>
<td>110</td>
</tr>
</tbody>
</table>

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Hybrid source: CLIC positrons baseline

- Crystal thickness few mm
- Amorphous thickness several mm
- \( e^+ \) yield \((N_{e^+}/N_{e^-})\) : 5 to 15
- \( \langle E_{e^+} \rangle \) : 40 to 70 MeV
- After the amorphous
  - Large angles & small dimension
- Matching lens
  - Adiabatic Matching Device (AMD)
AMD effect on the positron beam

- Few GeV $e^-$
- Pre-Injecteur Linac + Solenoid 0.5 T
- Distance few meters

- $<111> W$ Crystal

- $e^+$
- $\gamma$

- Amorphous

- $e^-$

- $P_x/P$

- $<E_{e^+}> : 50$ to $110$ MeV

- $e^+$ yield ($N_{e^+}/N_{e^-}$) : 1 to 4

- $B(z) = B_{min}/(1+\alpha z)$
  - $B_{max} = 6$ T, $B_{min} = 0.5$ T, $L=0.2$ m

- After the AMD
  - Small angles & large dimensions easier to transport

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Distance crystal – amorphous studies

- For fix amorphous target thickness the $e^+$ yield varies slightly
  - AMD large geometrical acceptance
- Long distance is preferable
  - Space for dipole implementation
  - $\gamma$ spot size $\Leftrightarrow$ energy density deposited

Up to the limit of the AMD geometrical acceptance

- The energy density is max. @ the target exit
- From SLC experiment

Peak Energy Density Deposition (PEDD)

PEDD[W] < 35 J/g
Energy deposition studies

- Increasing the distance contributes to lowering the PEDD

\[ P(kW) \]

PEDD & total power considerations

Selected parameters: 5 GeV, z=10 mm & d=2m

- Average power ≈ 10 kW
- PEDD ≈ 22 J/g (60% of margin before breakdown)
e⁺ phase space at the exit of the Pre-Injector Linac

- Downstream the AMD Pre-Injector Linac
  - 2 GHz cavities
  - \( E=10 \text{ MV/m} \)
- After 40 m
  - \( \epsilon_{\text{norm}}(\text{rms}) \approx 7.4 \times 10^{-3} \text{ m} \times \text{rad} \)
  - 200 MeV
  - \( \text{e}^+ \text{ yield } (\text{Ne}^+ / \text{Ne}^-) \approx 0.8 \)

- Is this yield enough?
- Recent studies request to increase by 25%-35% this yield
  - Increase by 25%-35% the e⁻ intensity
  - Average power : 12.5 – 13.5 kW
  - PEDD : 28 – 30 J/g
Conclusion

• CLIC e⁺ production and capture baseline for 3 TeV
  ✓ Positron yield
  ✓ Average total deposition reasonable
  ✓ PEDD below the maximum & still some margin

• Study in progress : hybrid solution for ILC
  – At the IP : 5 × the requested e+ for CLIC
  – Time structure modification (A. Variola)

• Further development
  – Continue the beam positrons transport studies : Injector, Pre Dumping Ring ...
  – 0.5 TeV CLIC option studies
  – Channelling effect implementation in Geant4