Positron beam emittance, DR cooling, acceptance and NO possibility of stacking

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Outline:

- Damping ring acceptance is examined
- Minimum spot size on the target is evaluated for:
  - Wiggler based source [WS],
  - Compton Linac Source [CLS] and
  - Compton Ring Source [CRS]
- Minimum positron emittance is evaluated and compared to DR acceptance
- Temperature rise in the stationary target is discussed to suggest maximum temperature does not depend on the size of the gamma beam.
- Analytical analysis of the capture optics demonstrate possibility of 100% capture in the pulsed CRS.
- No stacking possibility for the current, single DR, design is concluded at the end.

- Analyst is presented for vertical phase space only. Longitudinal plane does not affect the conclusions.

Damping Ring acceptance

RDR (accelerator)

$$Ax + Ay = 90\,mm\ rad \qquad J_x, J_y, J_s = 1,1,2$$

$$\gamma\varepsilon_x = 5\,\mu m\ rad \qquad \tau_x = 25.7ms$$

Initial normalized emittance (determined by the cooling time):

Vertical: $$5/300\,\mu m\,rad \cdot e^{2\,200ms/25.7ms} = 96mm\,rad$$

A very large vertical aperture of the DR ring ~ 3-4 cm make the 5 km ring very expensive. Two ring design might be a less expensive option.

There is a discrepancy Or safety by factor of 4 in the DR RDR (emittance and hard aperture are the same)

γ beam size on the target

- WS (150GeV, 200m):

$$\sigma_r \approx \frac{L_w}{2\gamma} + \frac{L_d}{\gamma} = \frac{200m}{2\cdot 3\cdot 10^5} + \frac{50..500m}{3\cdot 10^5} = 0.3mm + 0.2..1.6mm$$

  - Long drift is needed to make big enough spot at the target

- CLS (4GeV, 5IPs, 0.3m each)

$$\sigma_r \approx \frac{L_{IPs}}{2\gamma} + \frac{L_d}{\gamma} = \frac{3m}{2\cdot 8\cdot 10^3} + \frac{3..15m}{8\cdot 10^3} = 0.2mm + 0.4..1.9mm$$

- CRS (1.2GeV, 5IP, 3m each)

$$\sigma_r \approx \frac{L_{IPs}}{2\gamma} + \frac{L_d}{\gamma} = \frac{15m}{2\cdot 2.5\cdot 10^3} + \frac{3..15m}{2.5\cdot 10^3} = 3mm + 1.5..6mm$$

  - Emittance of the positron beam is limited by the gamma beam spot size on the target

Beam size at the target exit

$$\varepsilon_N = \gamma\sigma\sigma' = \gamma\sqrt{\sigma_\gamma^2 + \left(\sigma' L/2\right)^2}\,\sigma'; \quad \sigma' \approx \frac{14MeV}{E_{e^+}}\sqrt{\frac{L\rho}{X_0}}$$

	WS high K	WS low K	CLS	CRS
Top γ energy [MeV]	10	20	30	30
e^+ divergence [rad]	1.5	0.75	0.5	0.5
γ size [mm]	0.5	0.5	0.6	6
e^+ size Ti/W [mm]	15/1.5	7.5/0.75	5/0.5	5/0.5
Norm. emittance Ti/W [mm rad]	480/48	240/24	160/16	180/120

Estimates done for the top 50% energy selected
ILC dumping ring acceptance is: 90 mm rad,
(corresponds to ~30-45 mm rad emittance)

Target consideration

- For stationary round target cooled through side surface temperature does not depend on the beam size (only ratio of the beam to the target.)

$$\Delta T_{\max} \approx \frac{2P}{L\kappa}\ln\left(R_{target}/r_{beam}\right)$$

- Figure of merit (combination of the heat conductance κ, radiation length ($L=0.3\ X_0$), melting point T_{melt}) is 6.4kW for W and 4kW for T.

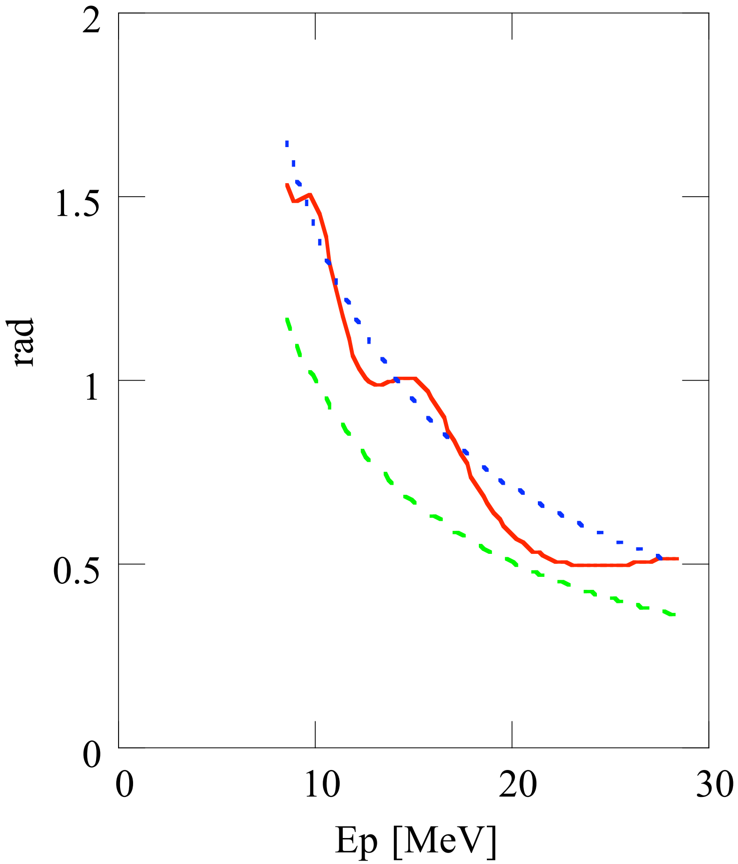
$$P_{\max} \approx 4\pi T_{\max}\, 0.3\frac{X_0}{\rho}\kappa\left[\ln\left(\frac{R^2}{\sigma_{beam}{}^2}\right)\right]^{-1}$$

Targets election: Rotating VS. stationary

- Rotating target has 10-100 times capture efficiency disadvantage.
- It is due to:
  - bigger spot and bigger output emittance
  - Limited choices of capture optics
- Difficult to build, service

- Stationary target might not survey ILC beam.
- It is likely doable for CLIC
- As small as practically possible target is optimal for "side cooling"
- Liquid target with diamond windows is a better option.

Capture optics



- There are analytical approximation of the capture dynamics. It is easy to show that ~100% can be captured and transported to DR in the pulsed CLS.
- It is challenging for CW mode of operation of the capture and accelerator for WS and CRS

Analytical estimates for the capture angular acceptance are shown in Red and Blue. Estimated angular spread for CLS is shown in green.

Conclusion:

- Only portion of the positrons produced on the target can be cooled to the required emittances in the DR
- Problems with target associated with a small fraction of accepted by DR positrons (<1% in WS).
- The heat load is 100 times smaller for the stationary target
- All "allowable" phase space is filled after first short.
- Stacking is not possible without DR (DRs) redesign