

A Proposal for Study of Structure and Dynamics of Energy/Matter Based on Production of γ -Ray at SLAC Facility

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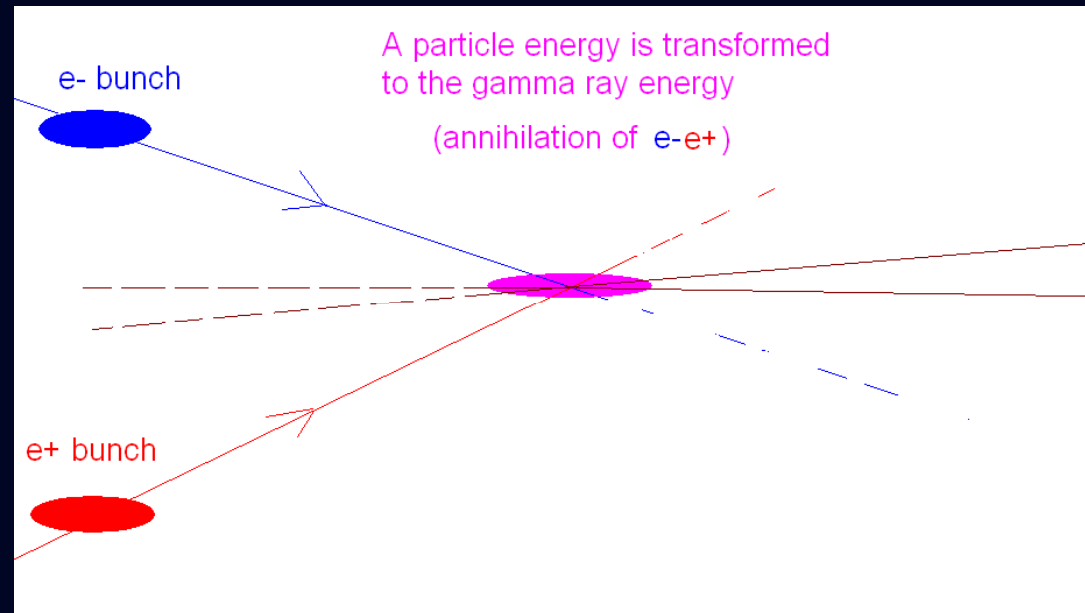
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Outline

- A Heart of Proposal
- Basic Physics
- A Potential Implementation at ASSET/FACET
- A Promising Implementation at PEP Storage Rings
- Conclusion

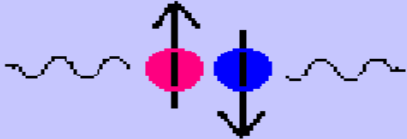

A Heart of Proposal



A co-linear colliding of
electron and positron bunches
at GeV energies ($\lambda_{\text{ph}} \ll \lambda_{\text{Compton}}$)

Basic Physics

There are two cases for e^+e^- scattering

para-positronium	ortho-positronium
$S = 0$	$S = 1$
	
Lifetime = 125 ps	Lifetime = 142 ns

A total spin of e^+e^- is zero ($S=0$)
Two γ - rays are created.
(a lifetime is 733 nsec @ 3GeV,
and 4.89 usec @ 20 GeV)

A total spin of e^+e^- is not zero ($S=1$)
Three γ - rays are created

(Culled from the published articles)

Basic Physics (cont.)

A precise calculation of positronium binding energy uses the Bethe-Salpeter equation, i.e. the similar to Hydrogen atom.

This allows for a rough estimate the binding energy

The lowest energy level binding energy of Ps atom is 6.8 eV, i.e.

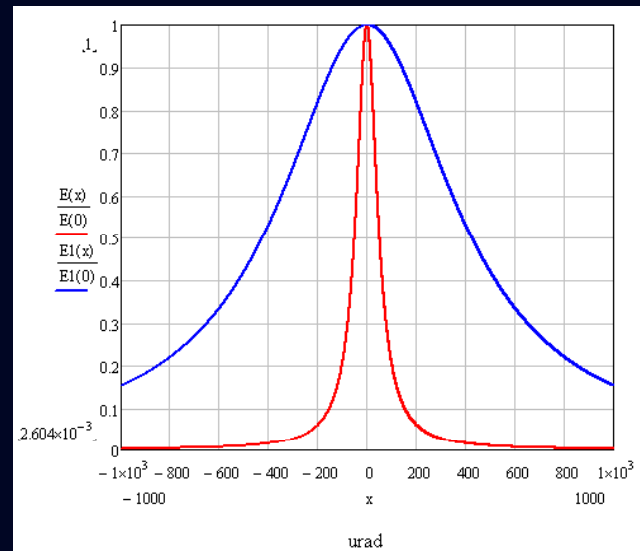
$$\frac{E_{bound}}{E_e} = 1.3 \cdot 10^{-5}$$

The Ps atom size is two times bigger than Hydrogen atom

Basic Physics (cont.)

There is no a creation of the Positronium atom if $\beta_{\perp} = \frac{v_{\perp}}{c} \geq 3.65 \cdot 10^{-3}$

A case for S=0 (two γ - rays) and there are no a bunch compression



$$t_{ph} \sim \frac{\sigma_z}{\beta_{\perp} \cdot c} \approx 0.5n \text{ sec}$$

Basic Physics (cont.)

- Uniform photon distribution in the $E_e < E_{ph} < 2E_e$ energy range for the forward direction
- Uniform photon distribution in the $0 < E < E_e$ energy range for the reverse direction
- A natural energy scan , a natural nuclear spectrometry for $\lambda_{ph} \ll \lambda_{Compton}$

Basic Physics (cont.)

- Simple formula for e⁺e⁻ cross-section is

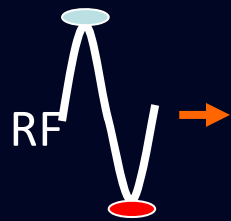
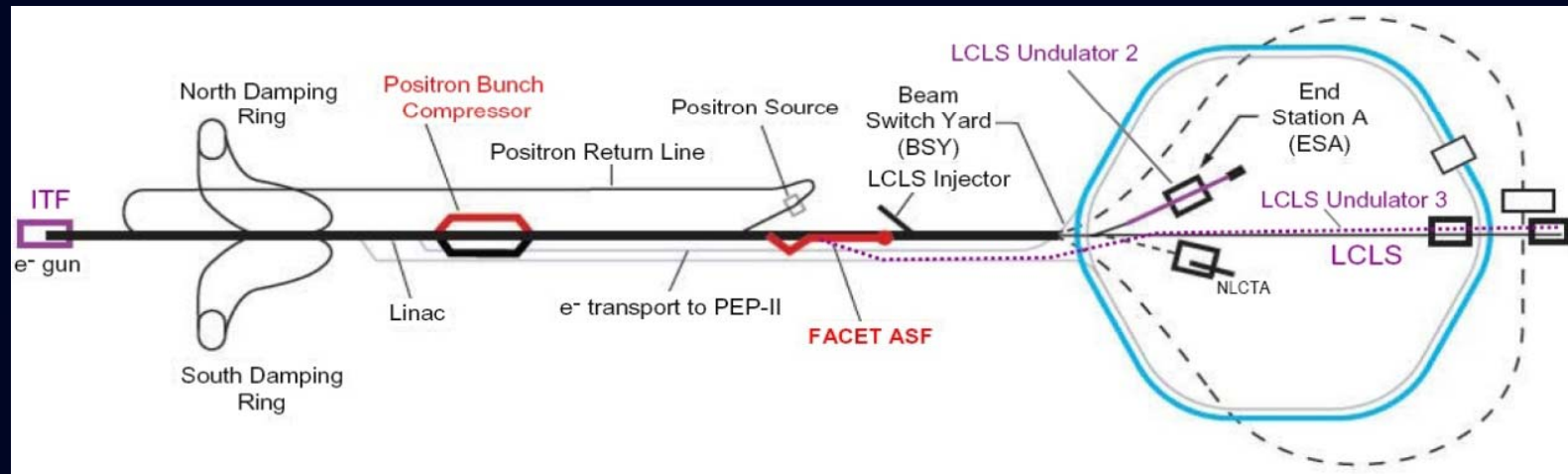
$$\sigma_{tot} = \frac{8\pi}{3} \left(\frac{\alpha \hbar}{m_e c} \right)^2 \simeq 0.665 \cdot 10^{-24} \text{ cm}^2$$

- Number of gamma-rays per pulse

$$N_{ph} = \frac{N_{e^+} N_{e^-}}{\sigma_z \sigma_r} \cdot \sigma_{tot} \simeq \frac{(3 \cdot 10^{10})^2}{0.04 \cdot 0.001} \cdot 0.7 \cdot 10^{-24} \simeq 16$$

- These photons will be concentrated in angle
+₋ 50 urad @ 10 GeV and
+₋ 400 urad @ 1.2 GeV

A Potential Implementation at ASSET/FACET



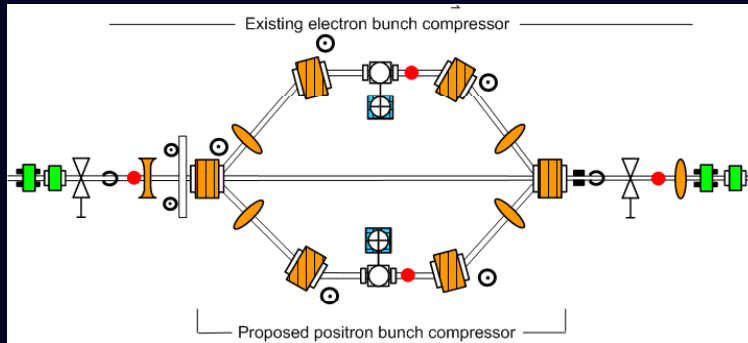
A beam loading with a 5.25 cm separation ?

A BBU limitation?

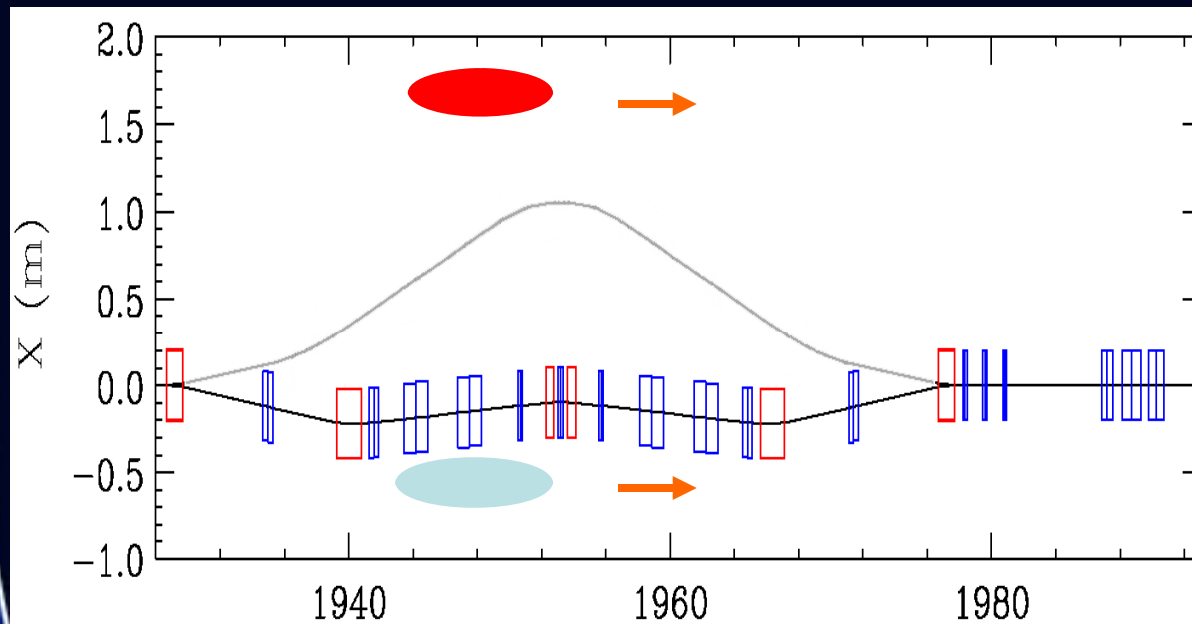
A beam optic to realize a small

$$\sigma_z, \sigma_{x,y}$$

A Potential Implementation at ASSET/FACET (cont.)



May this optic be a suitable for annihilation experiments?

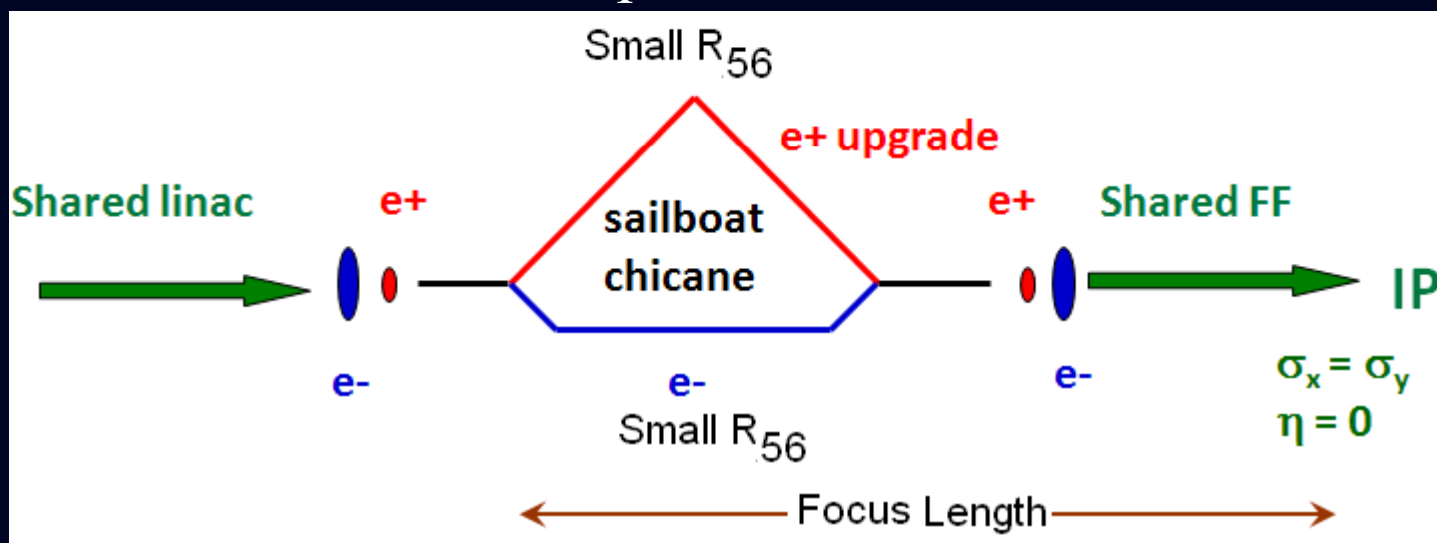


Focal Point:
 $\Delta z = 0.0\text{mm}$

Tolerances ?

Chicane optics in Sector-20

- Requires small $R_{56} < 1$ mm for final compression of bunch length
- Chicane optics is compatible with “sailboat chicane” upgrade
- The upgrade e^+ chicane is designed for longer path length to collide the electron and positron bunches

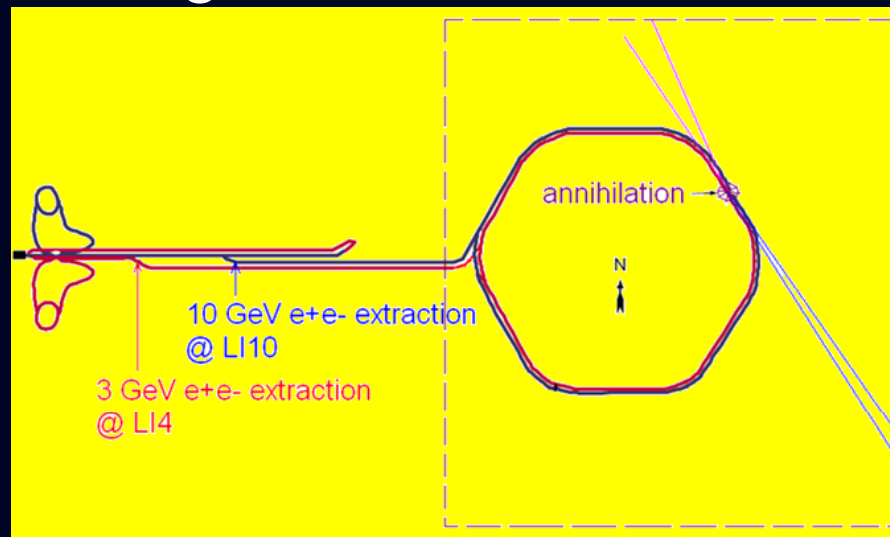


(This setup is similar to the FACET setup.
However there is no plasma system)

A Promising Implementation at the PEP Storage Rings

- PEP optic and RF system at 3 GeV for both rings
- PEP optic and RF system at 10 GeV for both rings

Update of the PEP injection for a co-linear colliding



Number of gamma-rays per bunch train and per one revolution $\sim 10^5$ (a train of gamma rays during 7.34 usec)

Conclusion

- A co-linear colliding of electron and positron bunches at GeV energies is proposed to produce the hard gamma rays ($\lambda_{\text{ph}} \ll \lambda_{\text{Compton}}$)
- The concept proposed here is unique and not pursued at other laboratories (This is a New Area for ASSET/FACET Research!)
- A Proposal relates to the SLAC Mission: A Study of Ultimate Structure and Dynamics of Energy/Matter

Conclusion (cont.)

The success of this proposal will open new areas of Chemistry with antimatter:

- new chemical dynamics
- exclusive production of parent ions by energy-tuning the positrons
- formation of antimatter compounds
- nano- and microscopic imaging of molecules, cells, and tumors
- multi-positron systems and their thermodynamics and chemical kinetics

o-Ps and p-Ps physics

- including speculations of dark matter (PAMELA & ATIC reported excesses in the e^+e^- cosmic rays)