POSITRON SOURCE OPTIONS FOR LINEAR COLLIDERS

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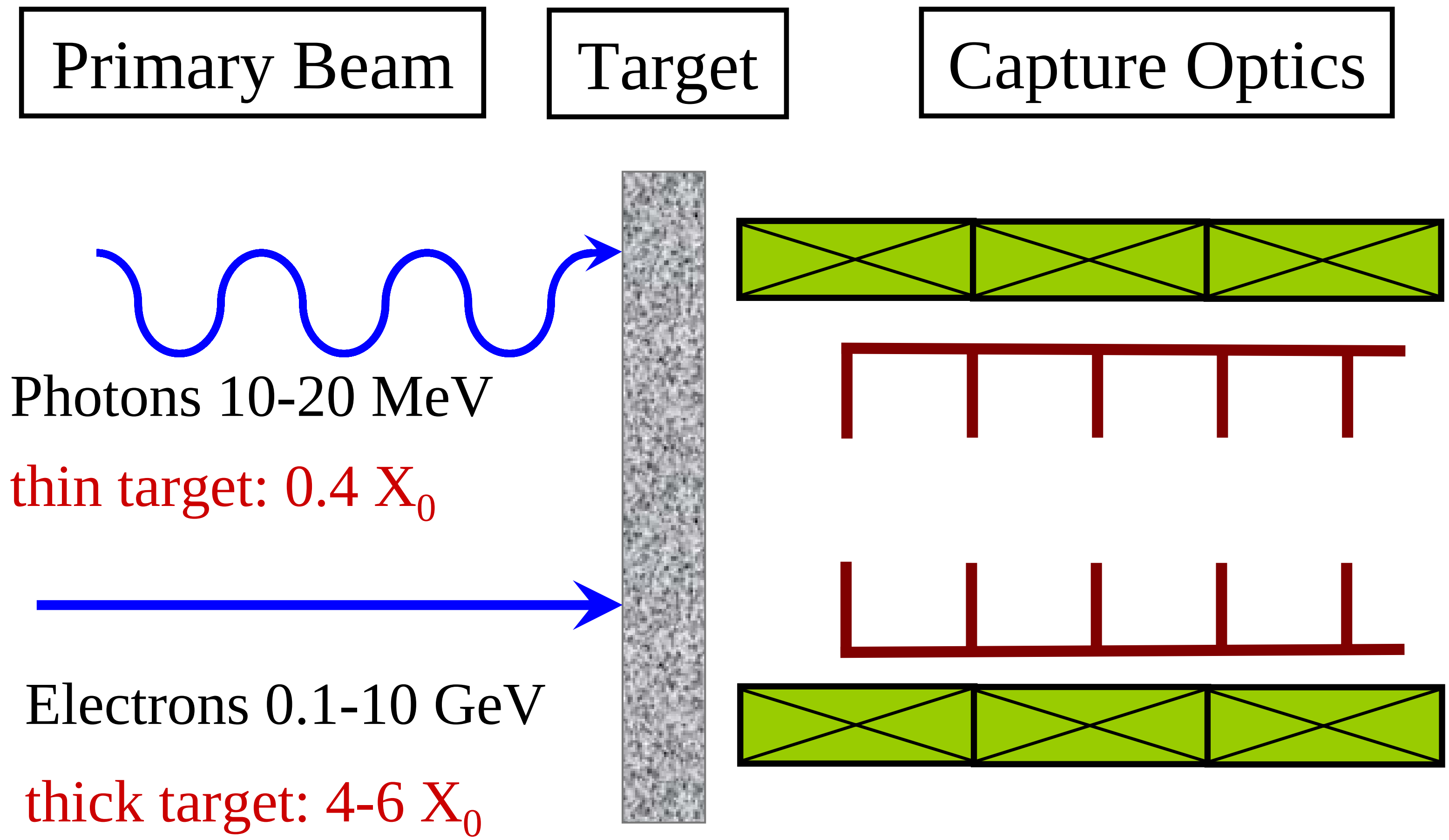
DESY

EPAC 04

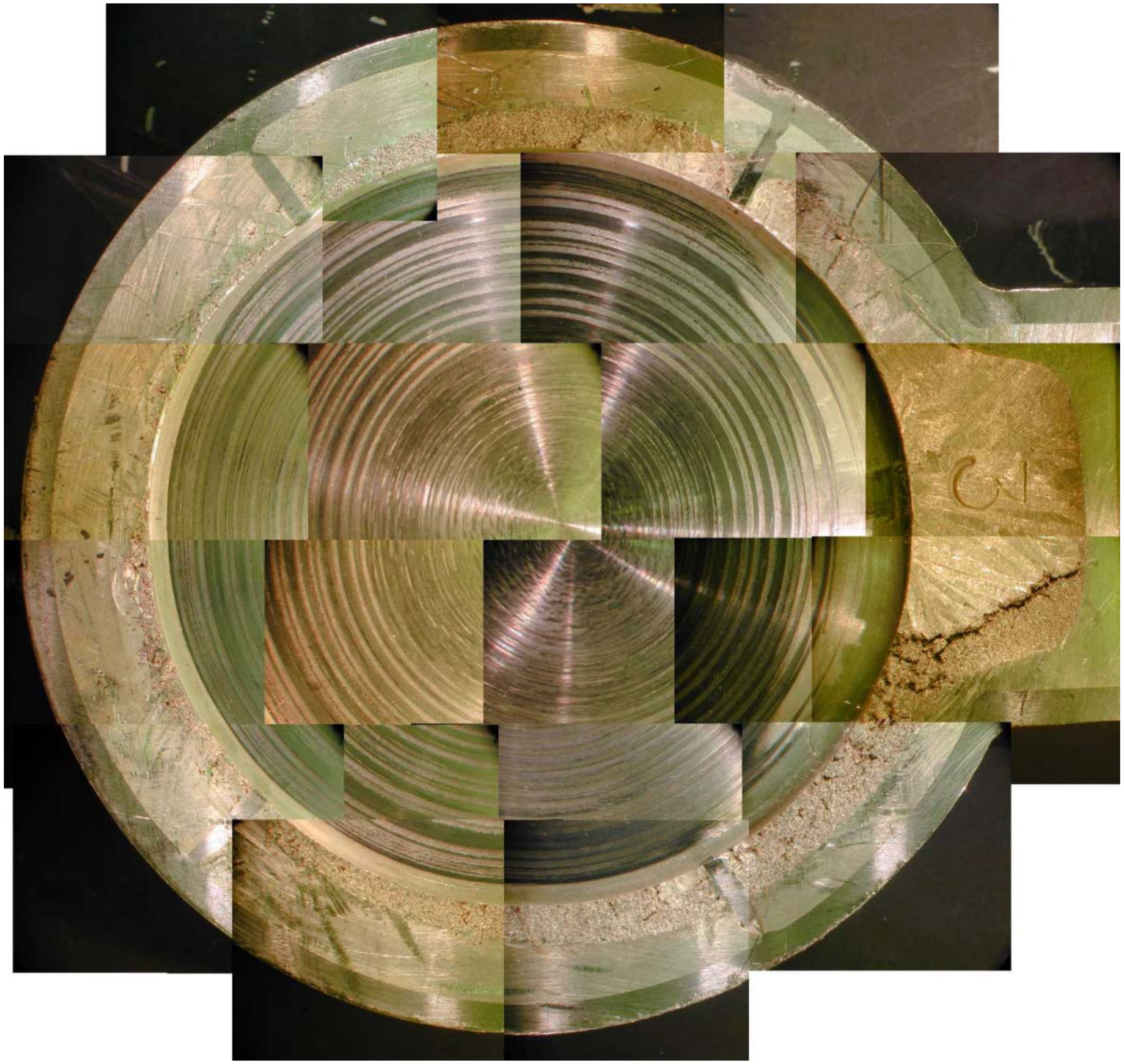
Contents:

- Basic design considerations
- Source Characteristics
- Polarized Positron Sources

How to built a Positron Source?



Target Damage at the SLC Converter Target



Parameters of existing and planed positron sources

	rep rate	# of bunches per pulse	# of positrons per bunch	# of positrons per pulse
TESLA	5 Hz	2820	$2 \cdot 10^{10}$	$5.6 \cdot 10^{13}$
NLC	120 Hz	192	$0.75 \cdot 10^{10}$	$1.4 \cdot 10^{12}$
SLC	120 Hz	1	$5 \cdot 10^{10}$	$5 \cdot 10^{10}$
DESY positron source	50 Hz	1	$1.5 \cdot 10^{9}$	$1.5 \cdot 10^{9}$

The Problem: Target Heating

$$\Delta T = 2 N_{pos} \eta \frac{E_{dep}}{c \cdot A}$$

$$E_{dep} = 2 \frac{\mathrm{MeV} \cdot \mathrm{cm}}{\mathrm{g}}$$

$$1/\eta = \text{capture efficiency}$$

$$c = \text{heat capacity}$$

$$A = \text{source area}$$

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Number of Positrons / Source Area

Example of the rotating target for TESLA:

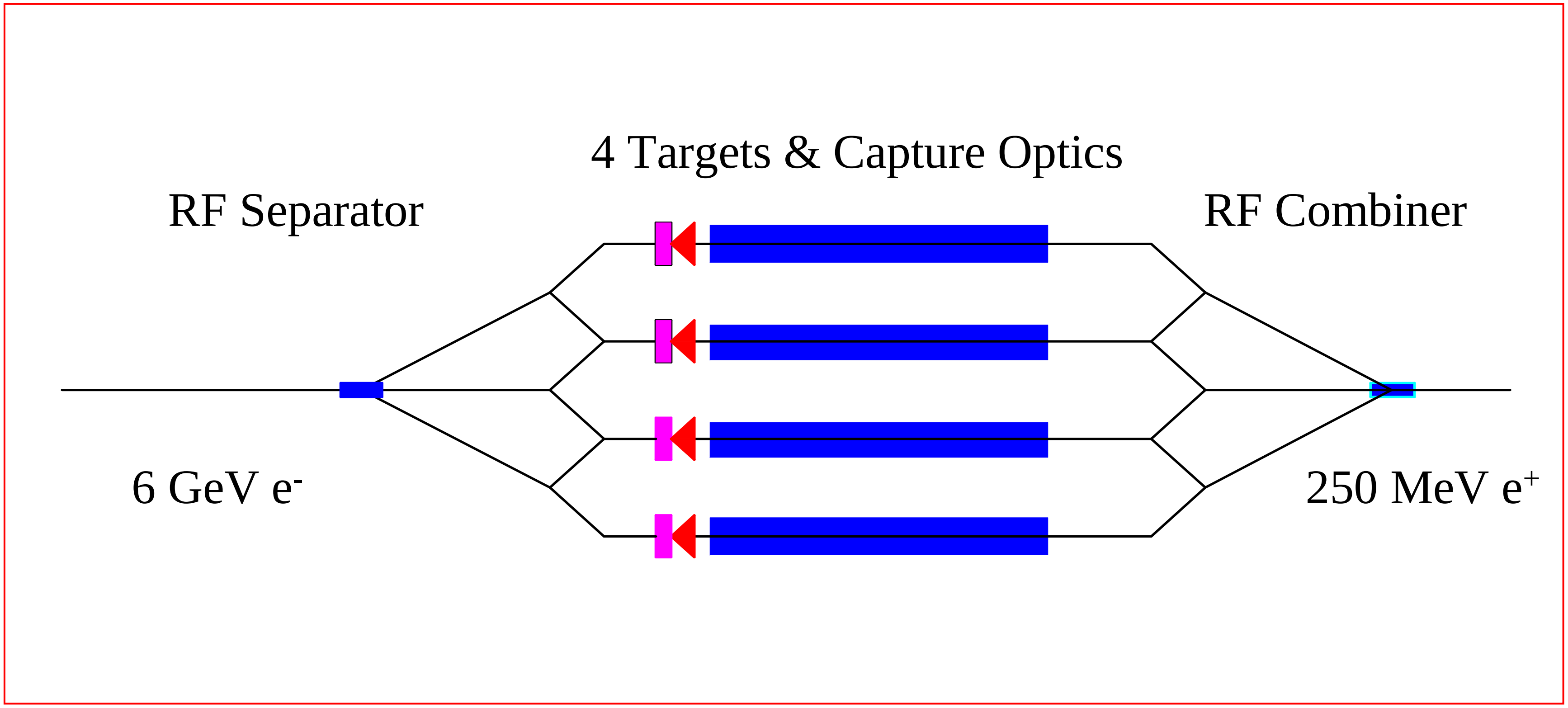
0.8 m diameter

1250 revolutions per minute

➡ 52 m/s on the circumference

➡ 4 cm in a pulse train of 0.8 ms

NLC Positron Target System Layout



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Heat Capacity of the Target Material

Low Z materials have a higher heat capacity (Dulong Petit Rule)

but

high Z materials give a higher positron yield.

Target Material

The escape depth S_{Escape} from which a positron of energy E_{pos} can reach the target surface is estimated as:

$$S_{Escape} / X_0 = \frac{E_{pos}}{E_{dep} \cdot \rho \cdot X_0}$$

$$E_{dep} = 2 \, \frac{\mathrm{MeVcm}^2}{\mathrm{g}}$$

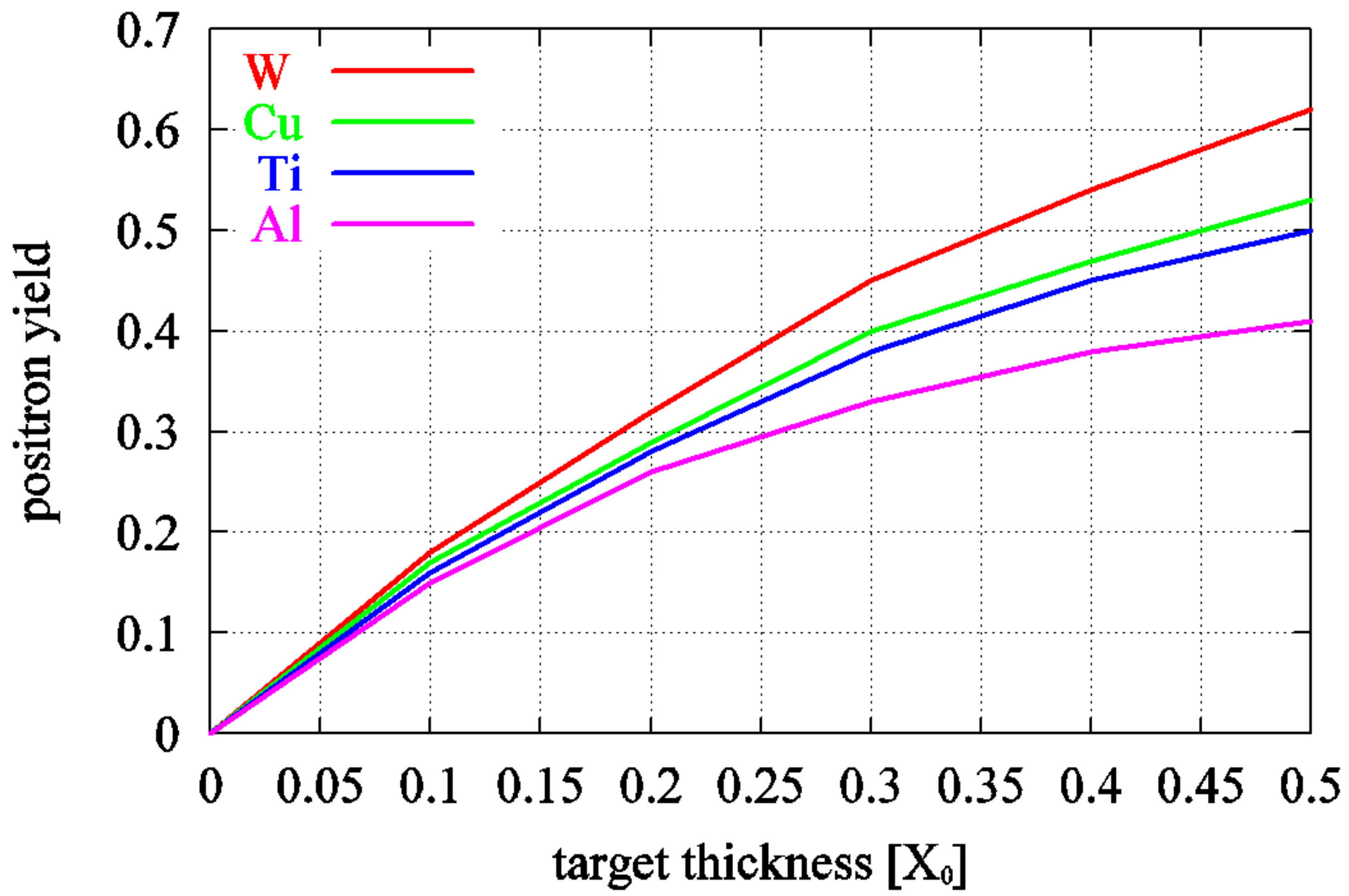
$\rho =$ density of the material

Target Material

Escape depth for 10 MeV positrons:

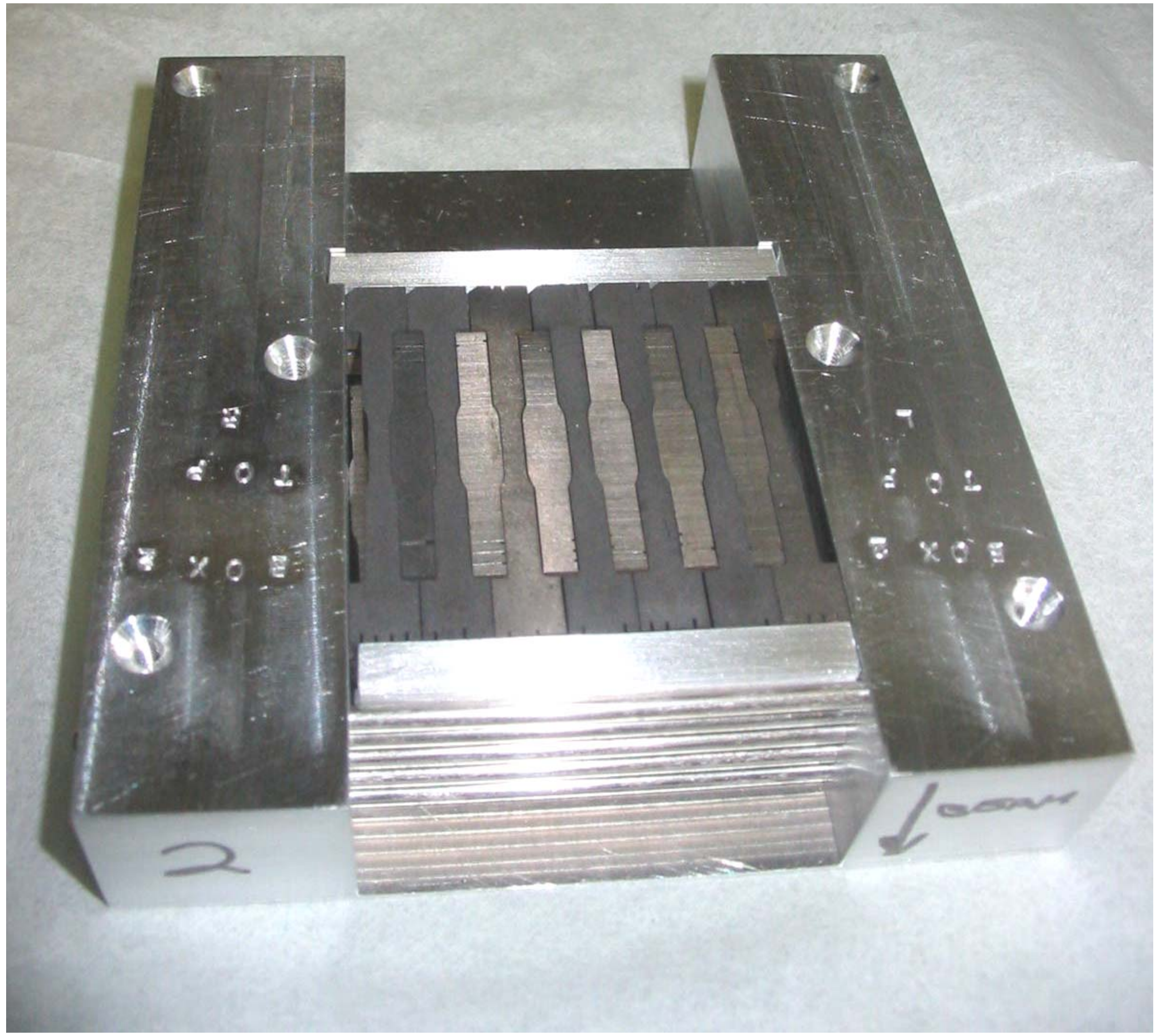
Material	Z	S_{Escape}/X_0
W	74	0.74
Cu	29	0.39
Ti	22	0.31
Al	13	0.21

Positron Yield vs. Target Thickness for a Photon based Source



Radiation Damage Material Test at BNL

collaborative effort of SLAC and other labs



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How to Increase the Capture Efficiency?

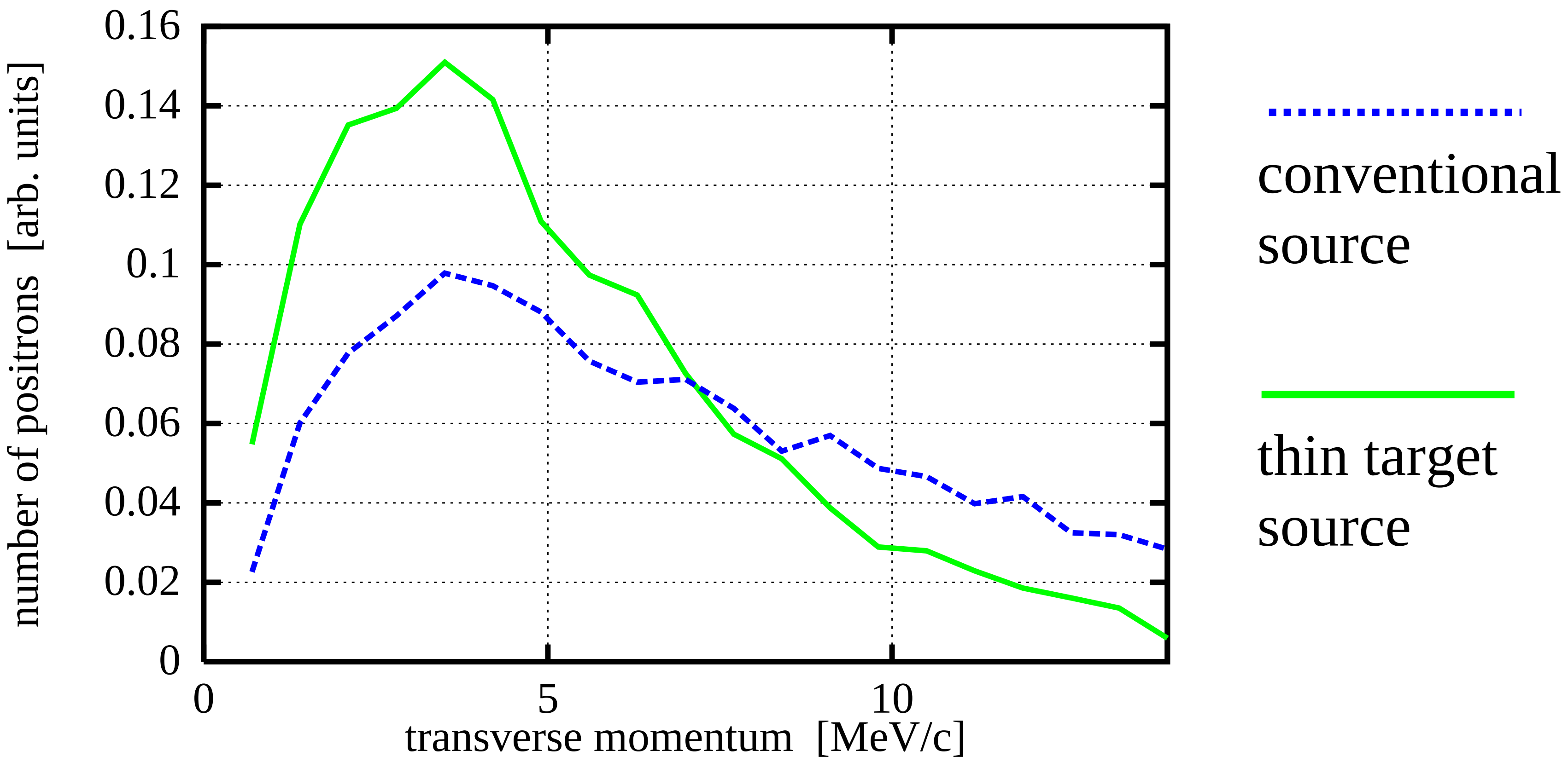
Increase the acceptance of the capture optics

➡ requires a Predamping ring with large acceptance

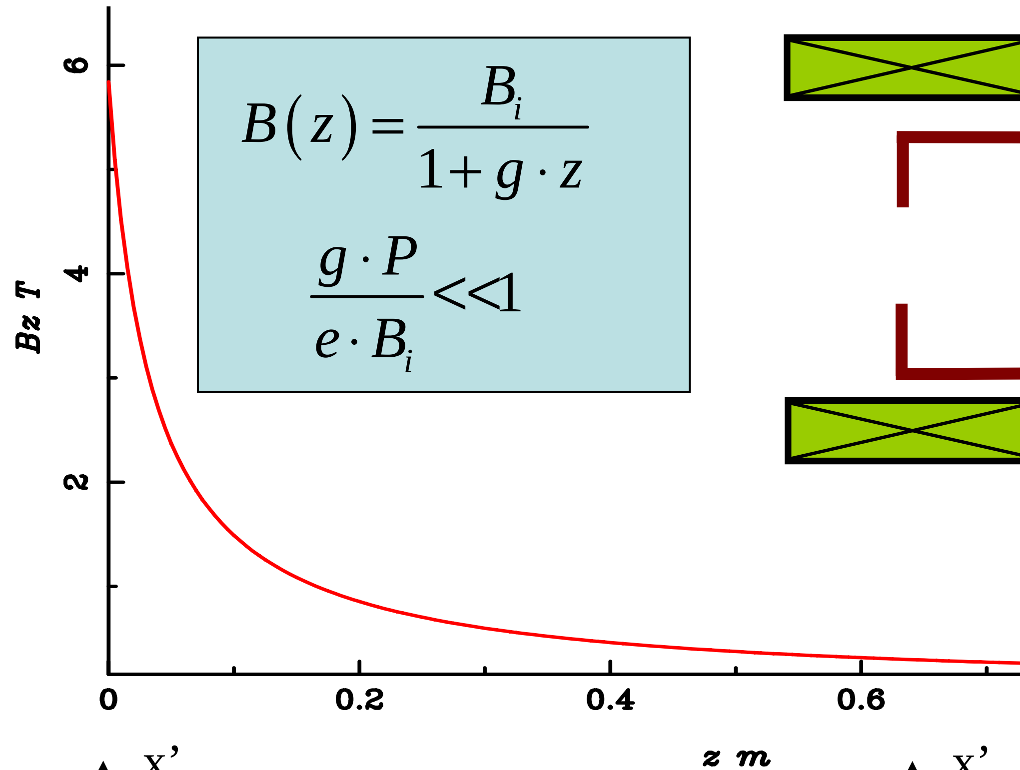
Improve the positron emittance

➡ photon based positron source with thin target

Transverse momenta

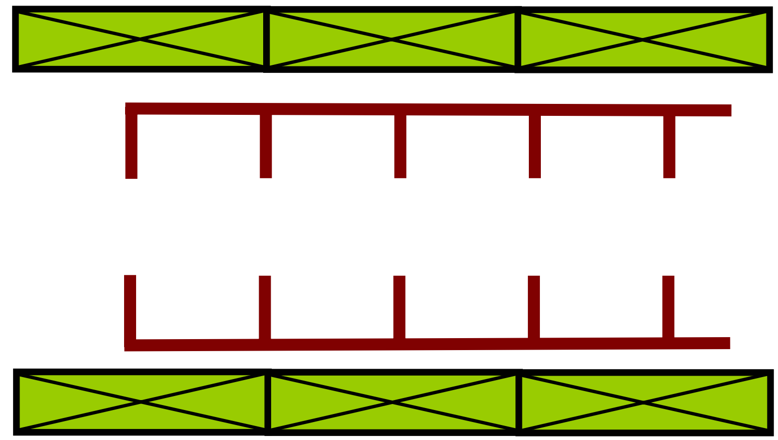


The capture optics



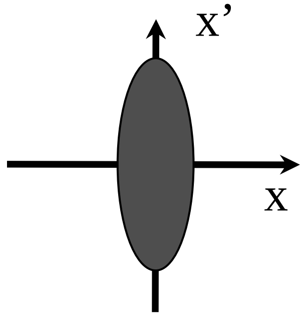
$$B(z) = \frac{B_i}{1 + g \cdot z}$$

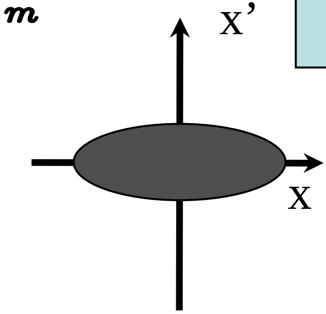
$$\frac{g \cdot P}{e \cdot B_i} << 1$$



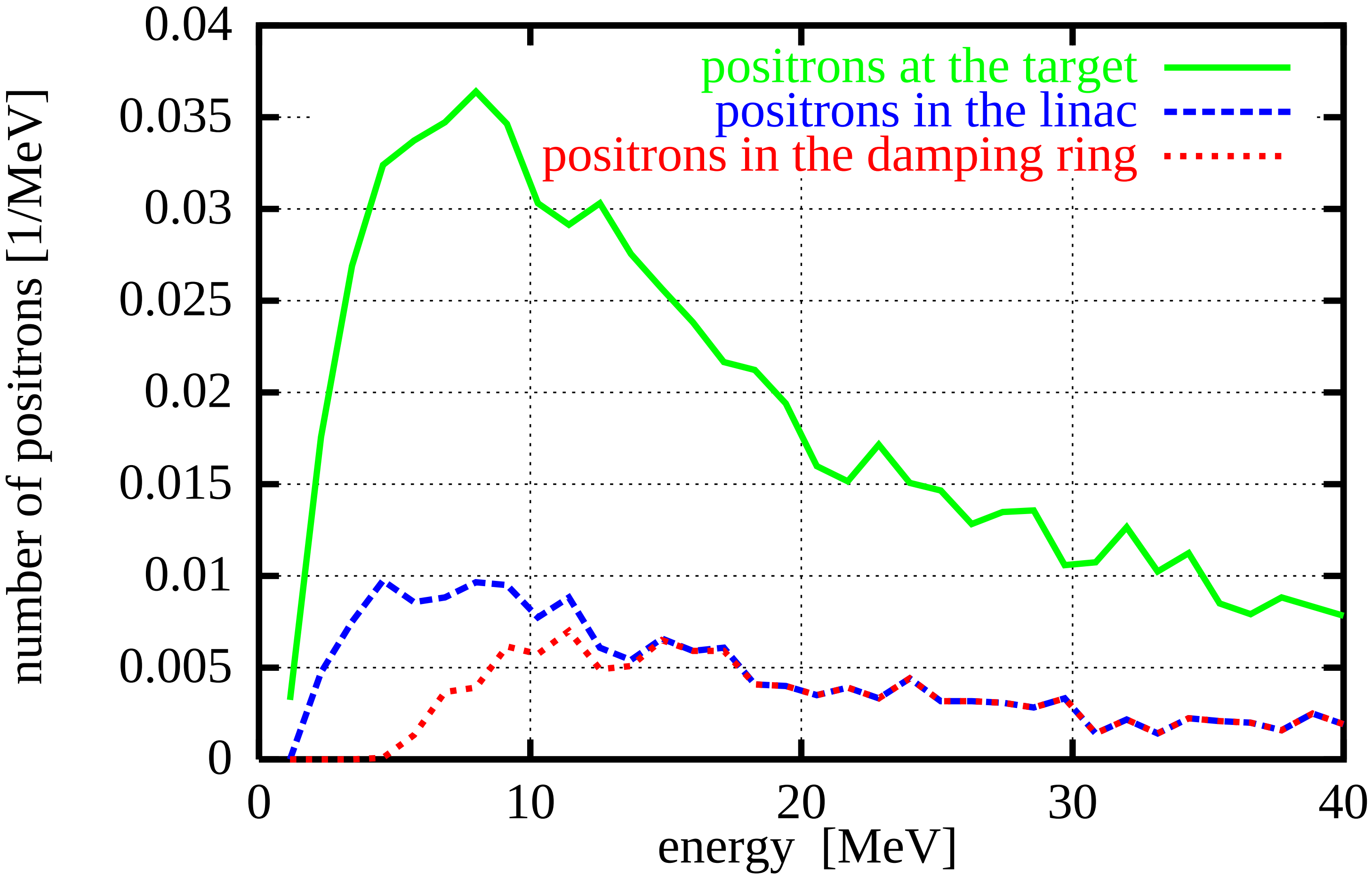
low frequency (L-band)

- large iris radius
- long wave length

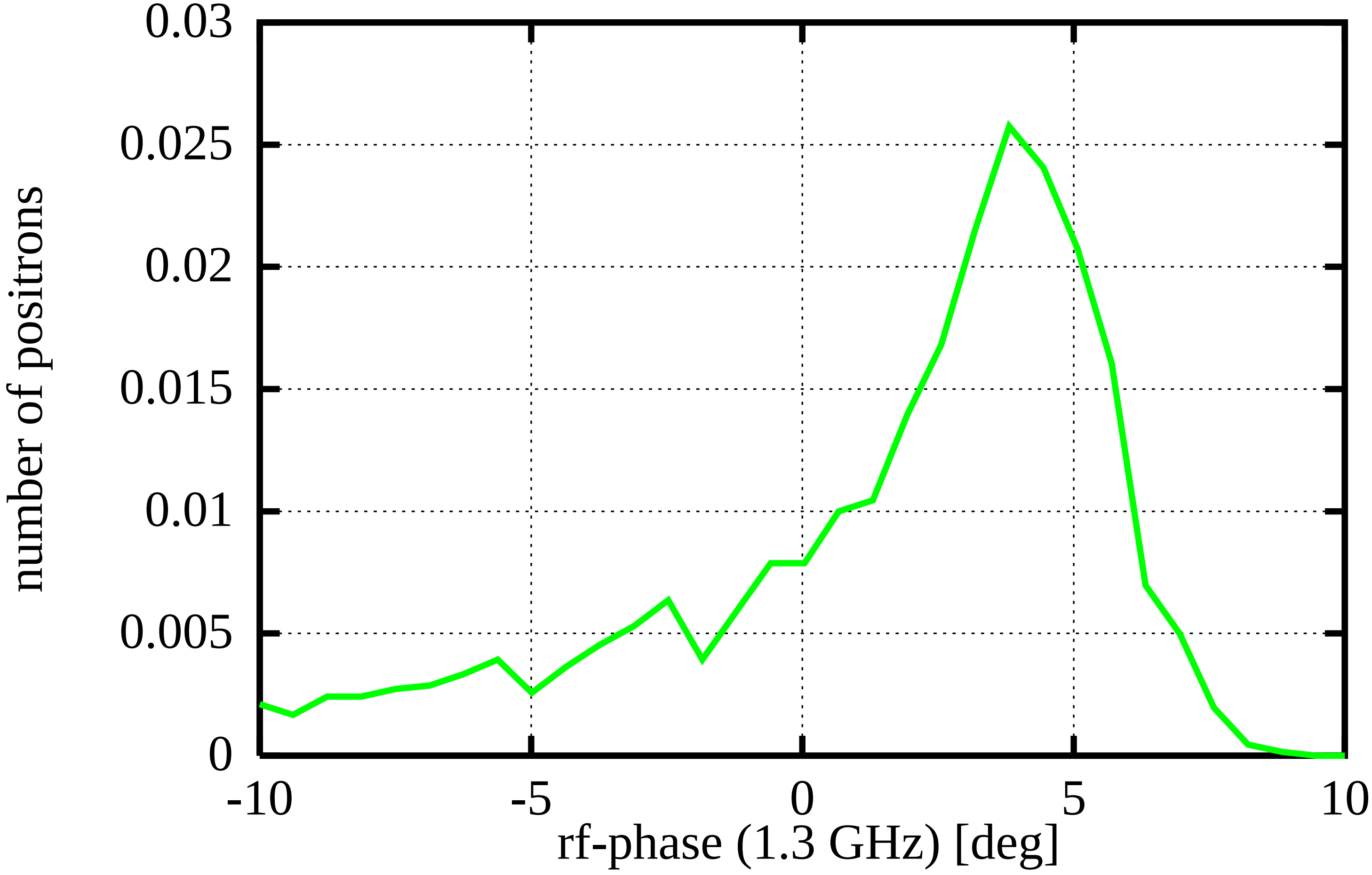




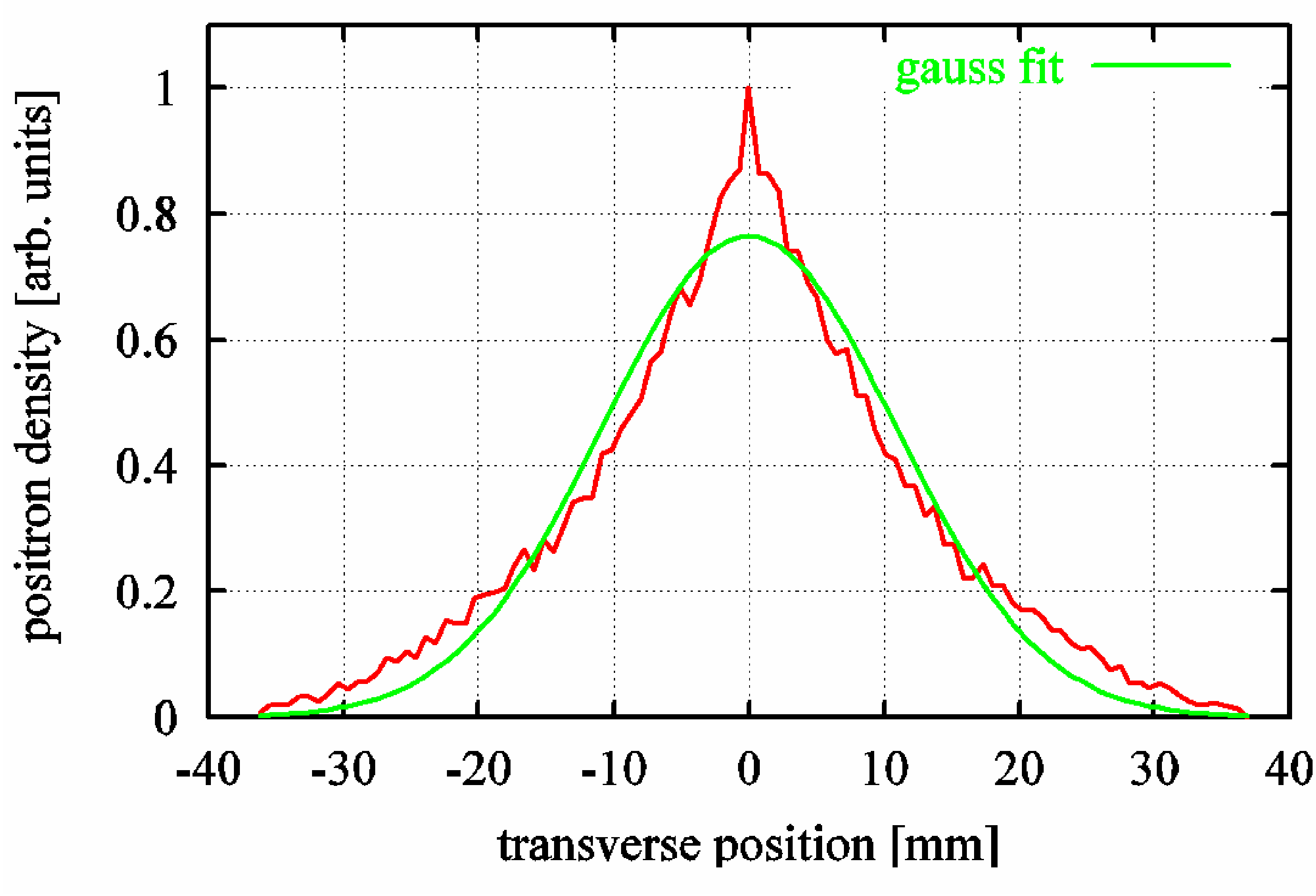
Source characteristics: Energy distribution



Source characteristics: Longitudinal beam shape



Source characteristics: Transverse beam shape



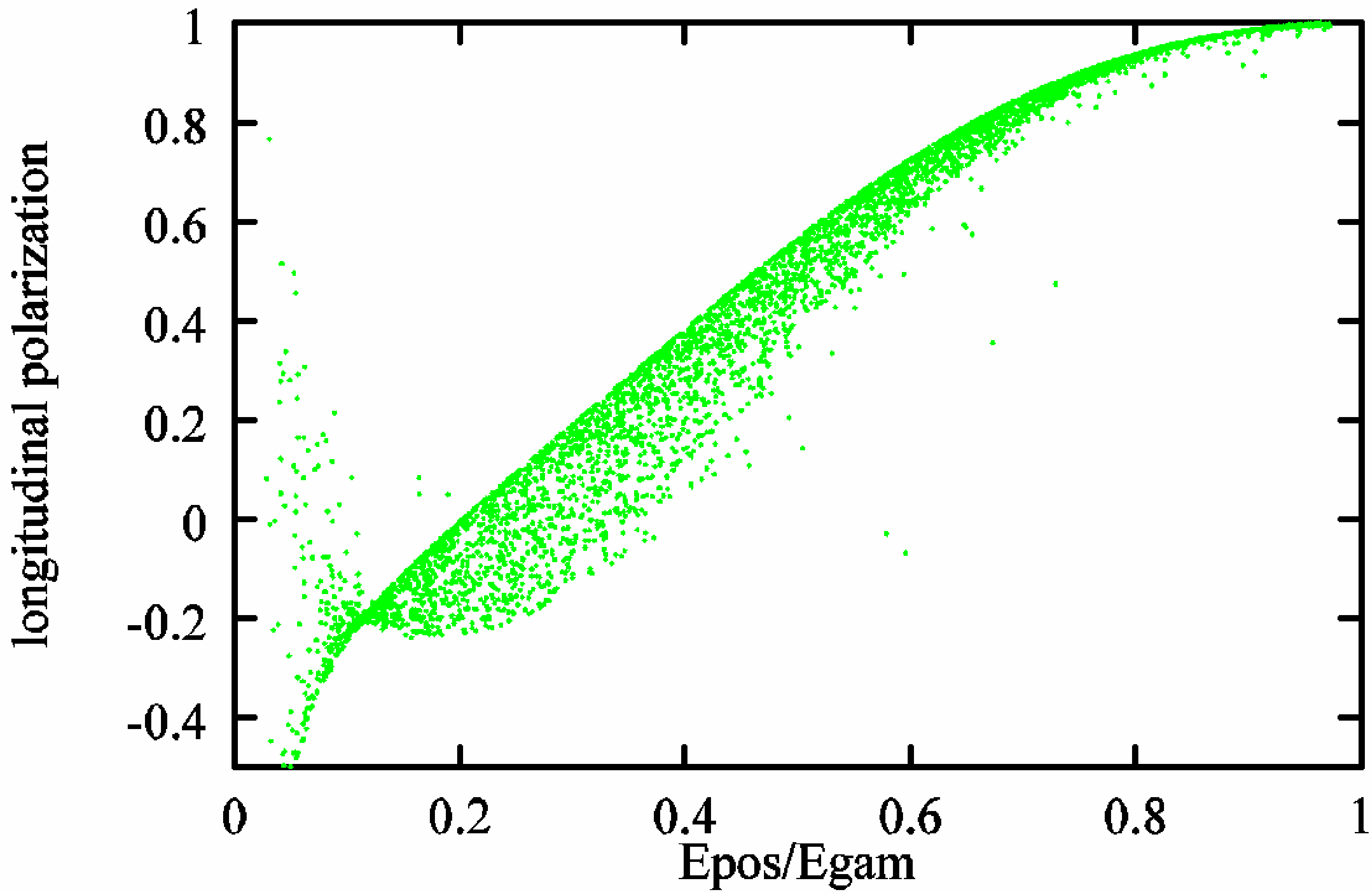
Polarized Positron Sources

For the production of polarized positrons circularly photons are required.

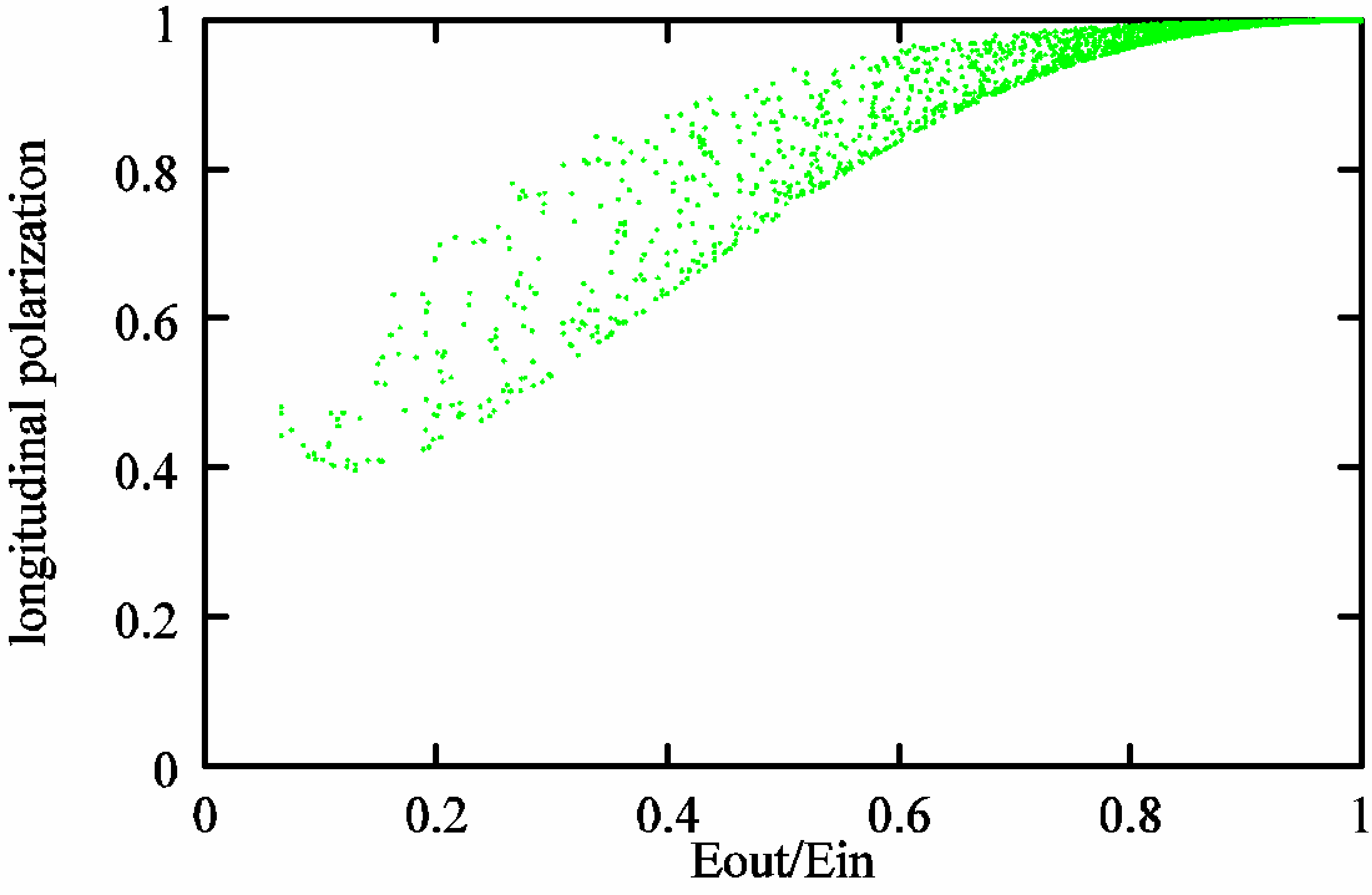
Methods to produce circularly polarized photons of 10-60 MeV are:

- radiation from a helical undulator
- Compton backscattering of laser light off an electron beam

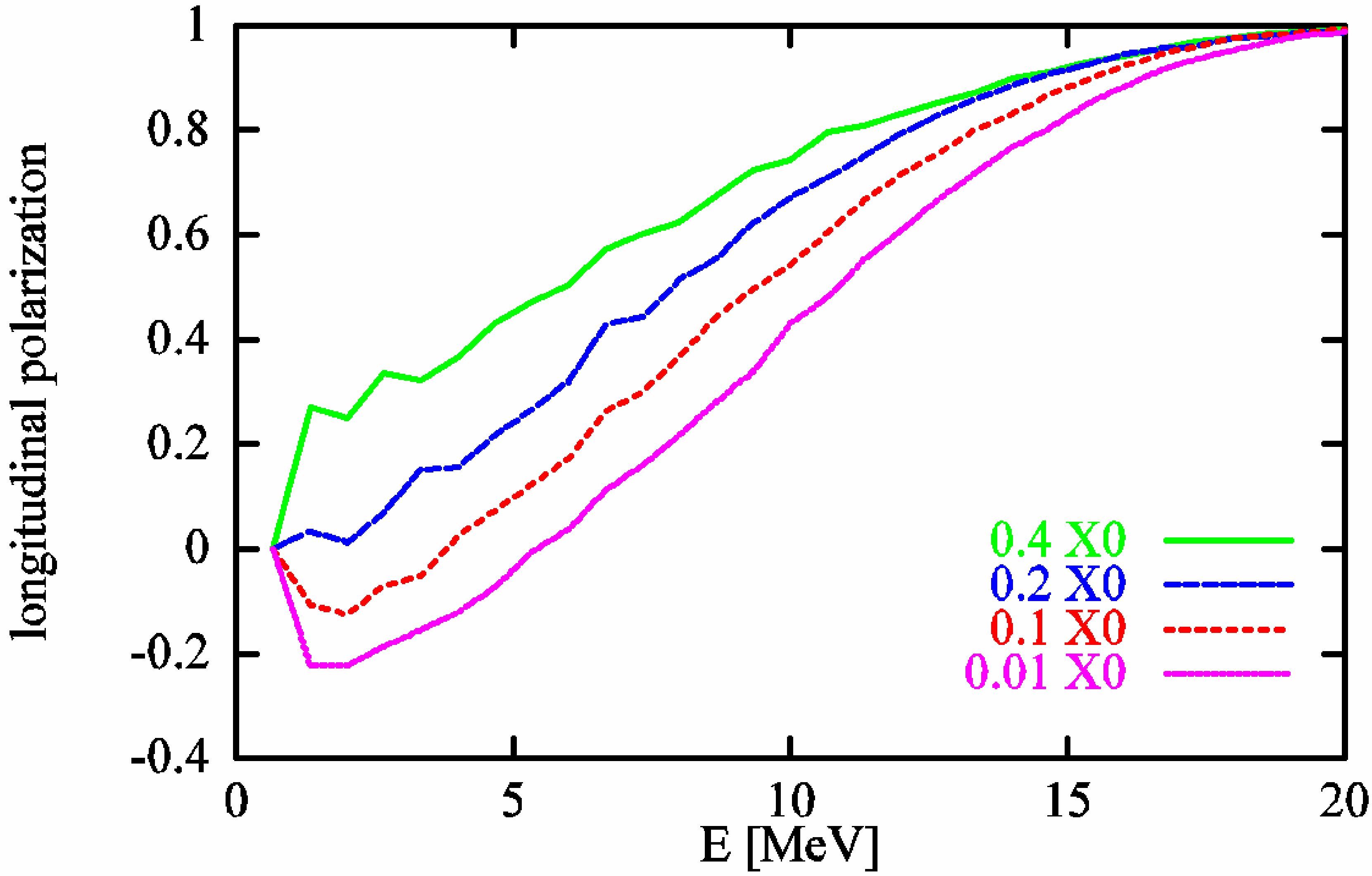
Polarization Transfer in Pair Production



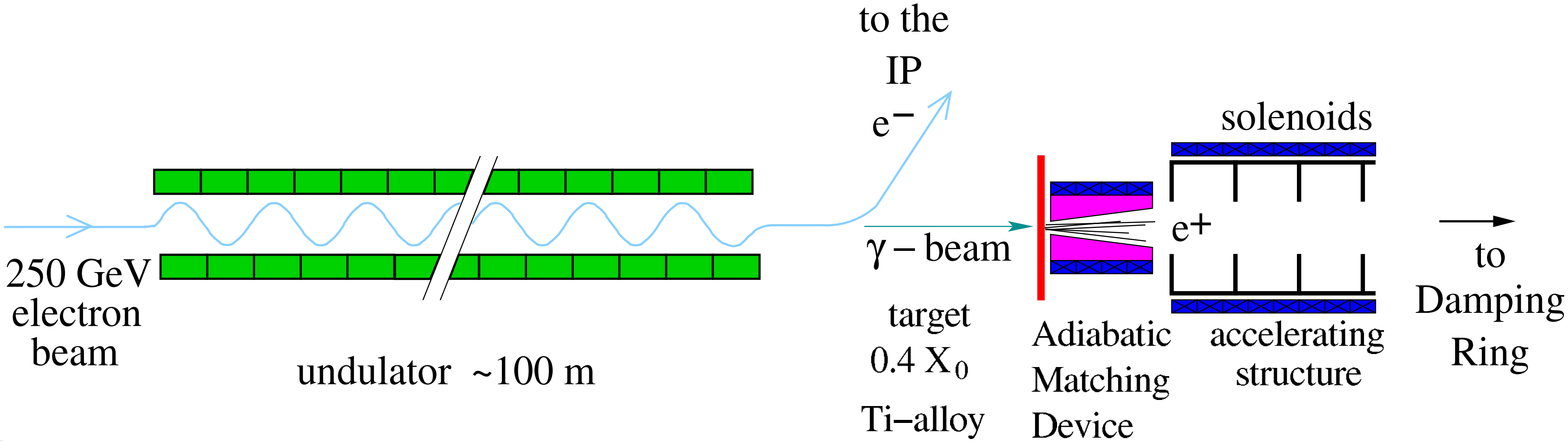
Polarization loss due to Bremsstrahlung



Polarization vs. Target Thickness

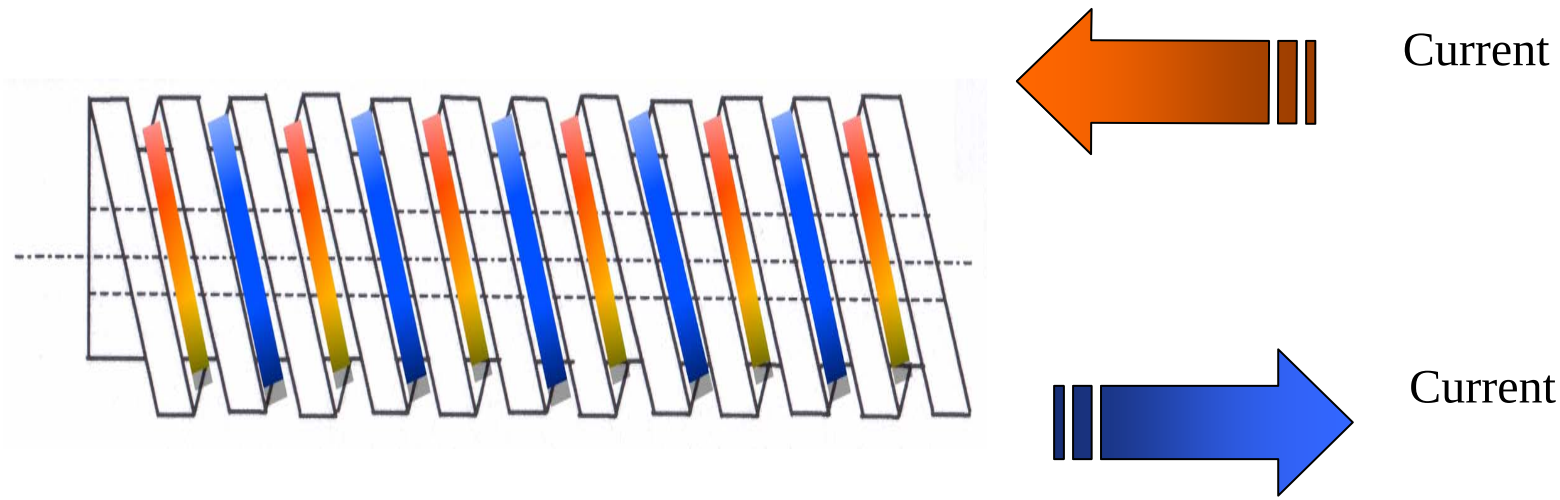


Undulator Based Positron Source



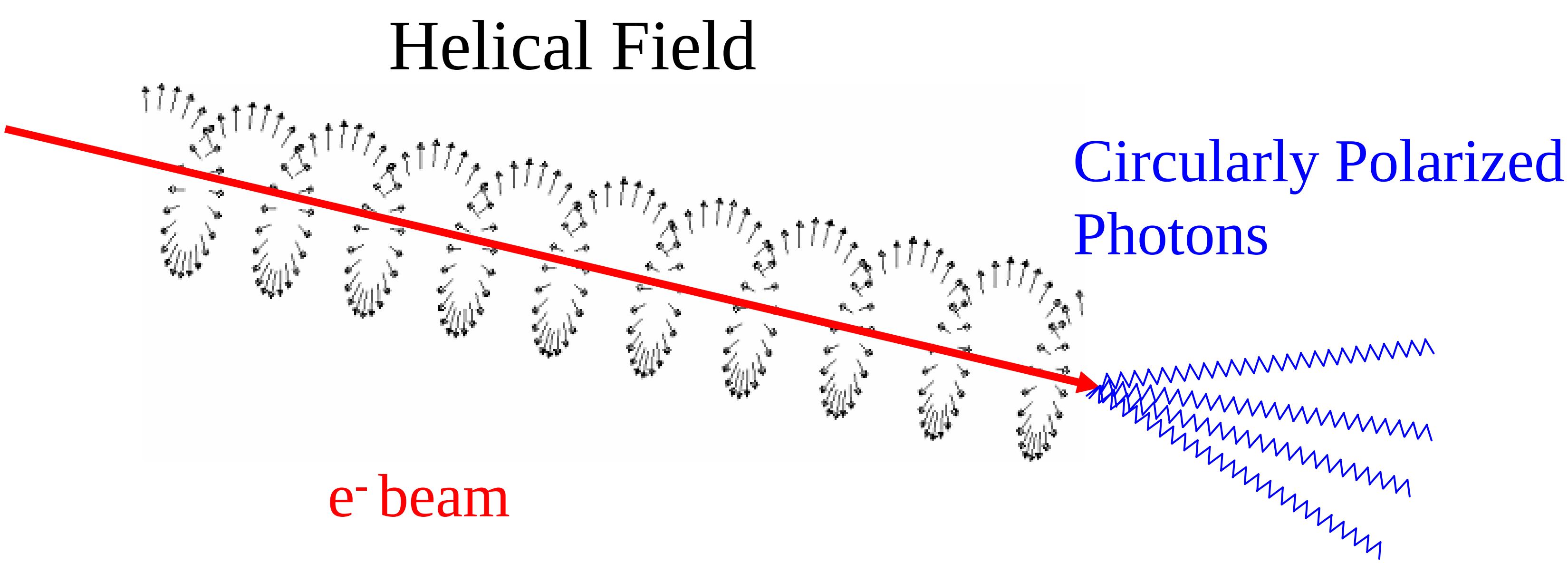
Super Conducting Design

- Ribbon-wire wound in a double helix

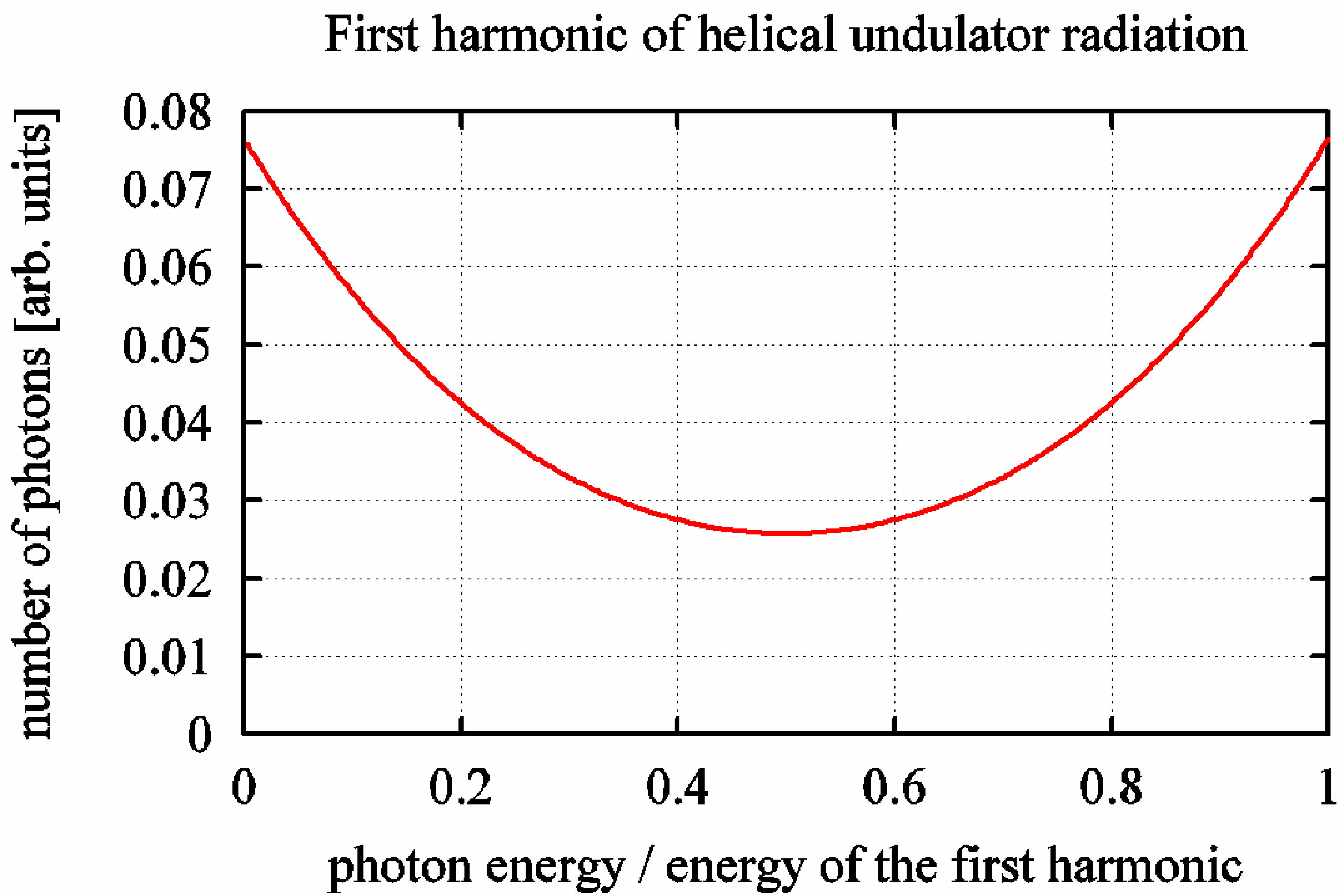


Helical Undulator

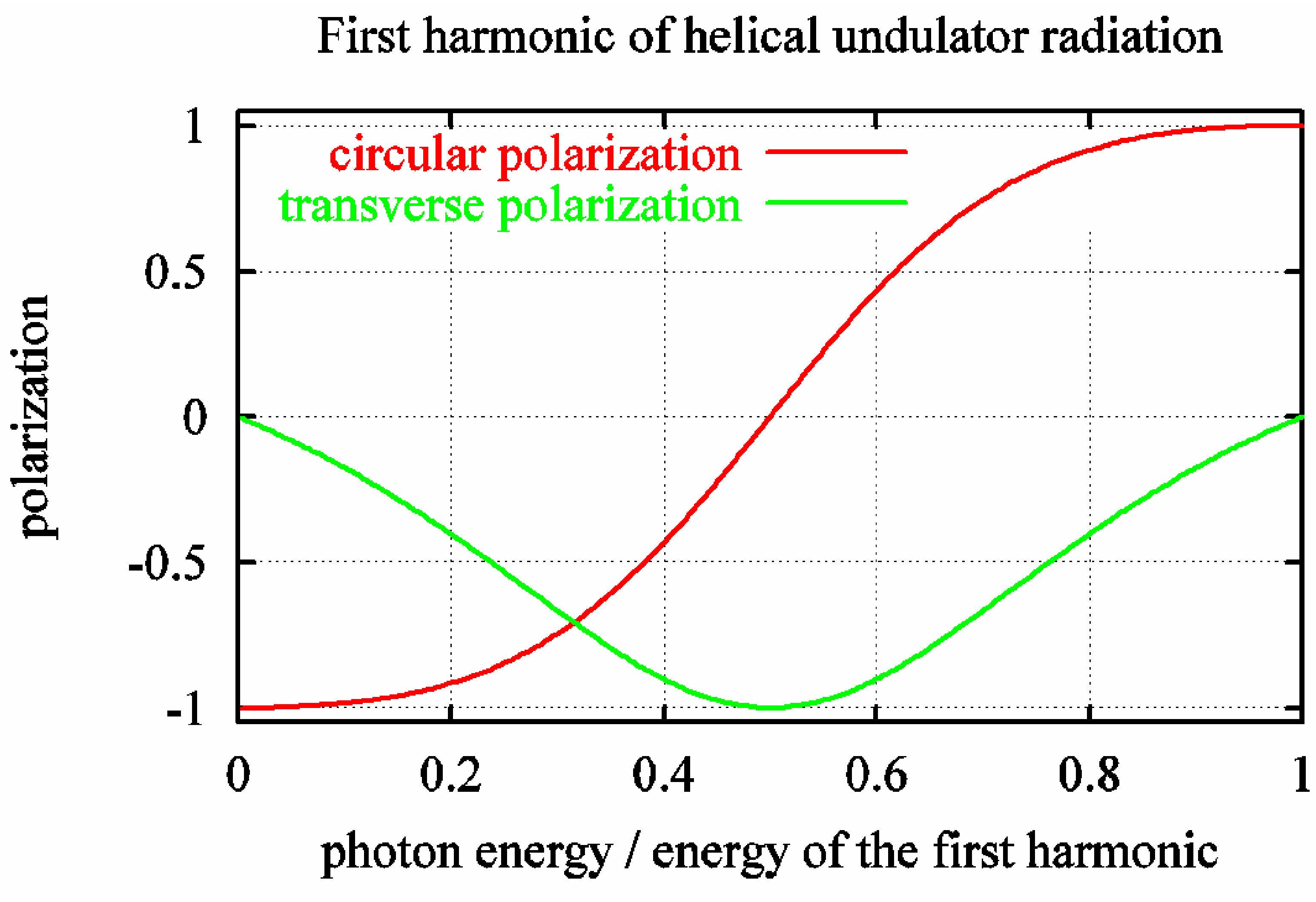
- Rotating Dipole Field in the Transverse Planes
- Electrons follow a “helical” path
- Circularly polarised radiation is emitted



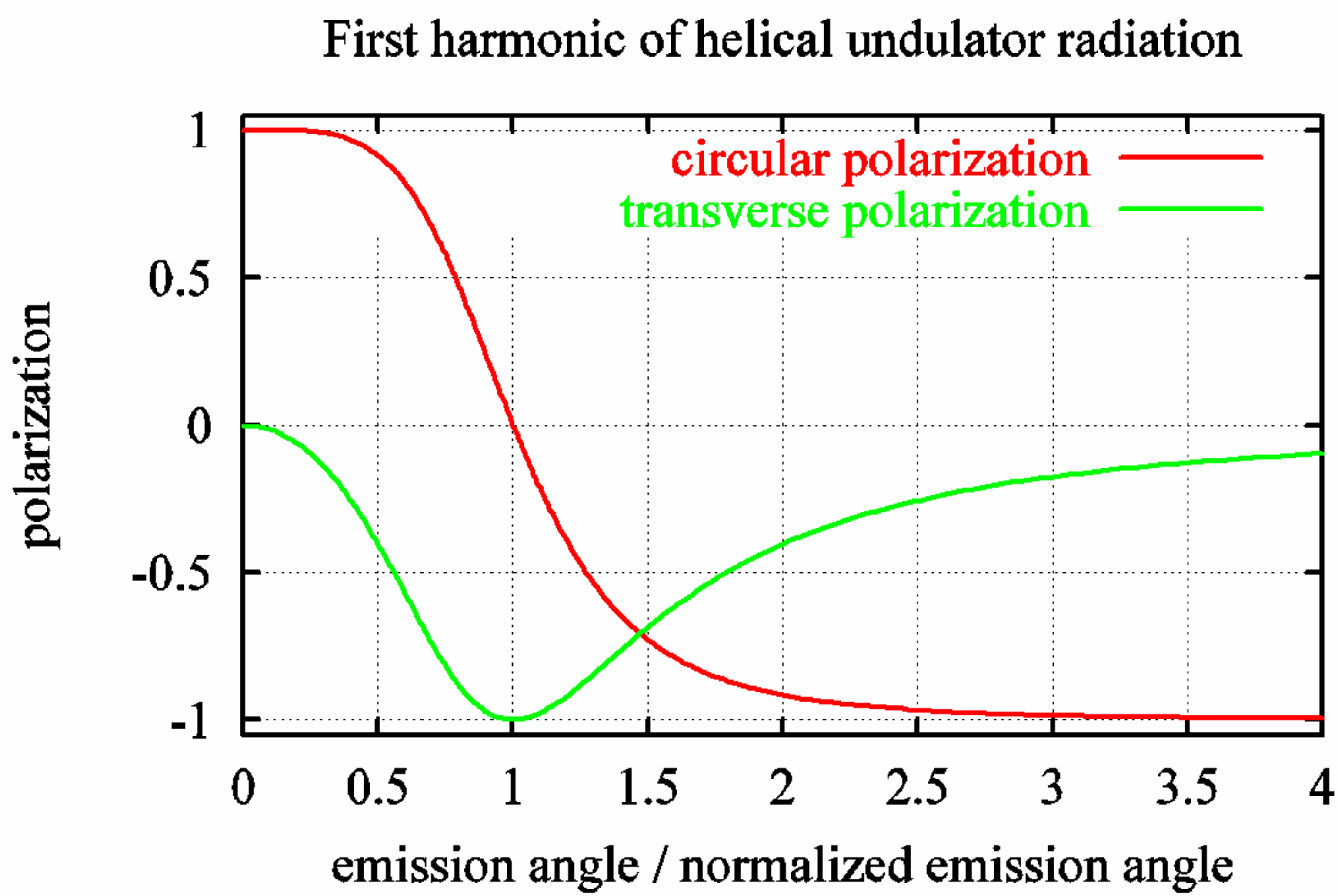
Number of Photons vs. Energy



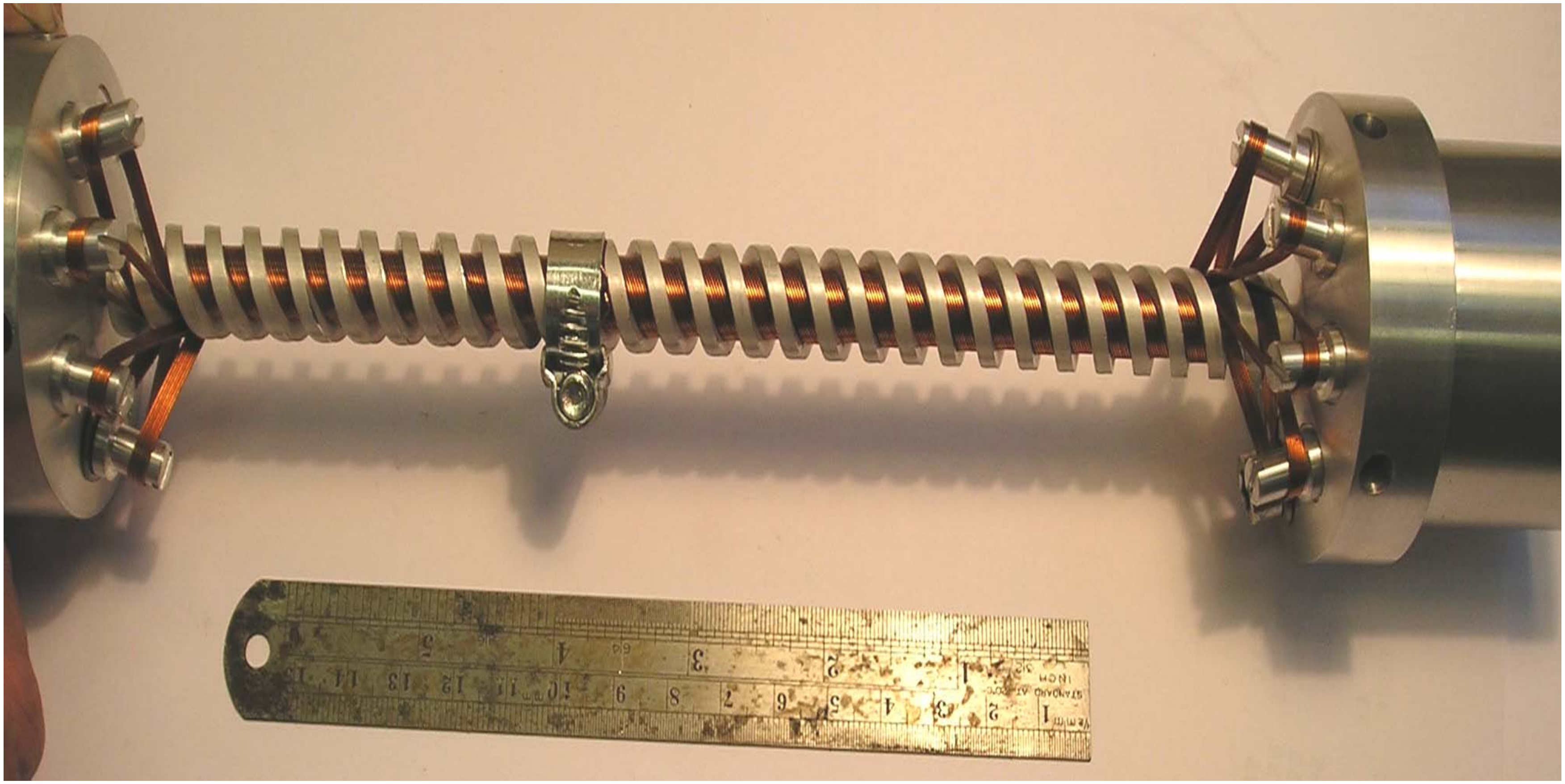
Polarization vs. Energy



Polarization vs. Emission angle



Model of the Prototype Helical Undulator at Daresbury



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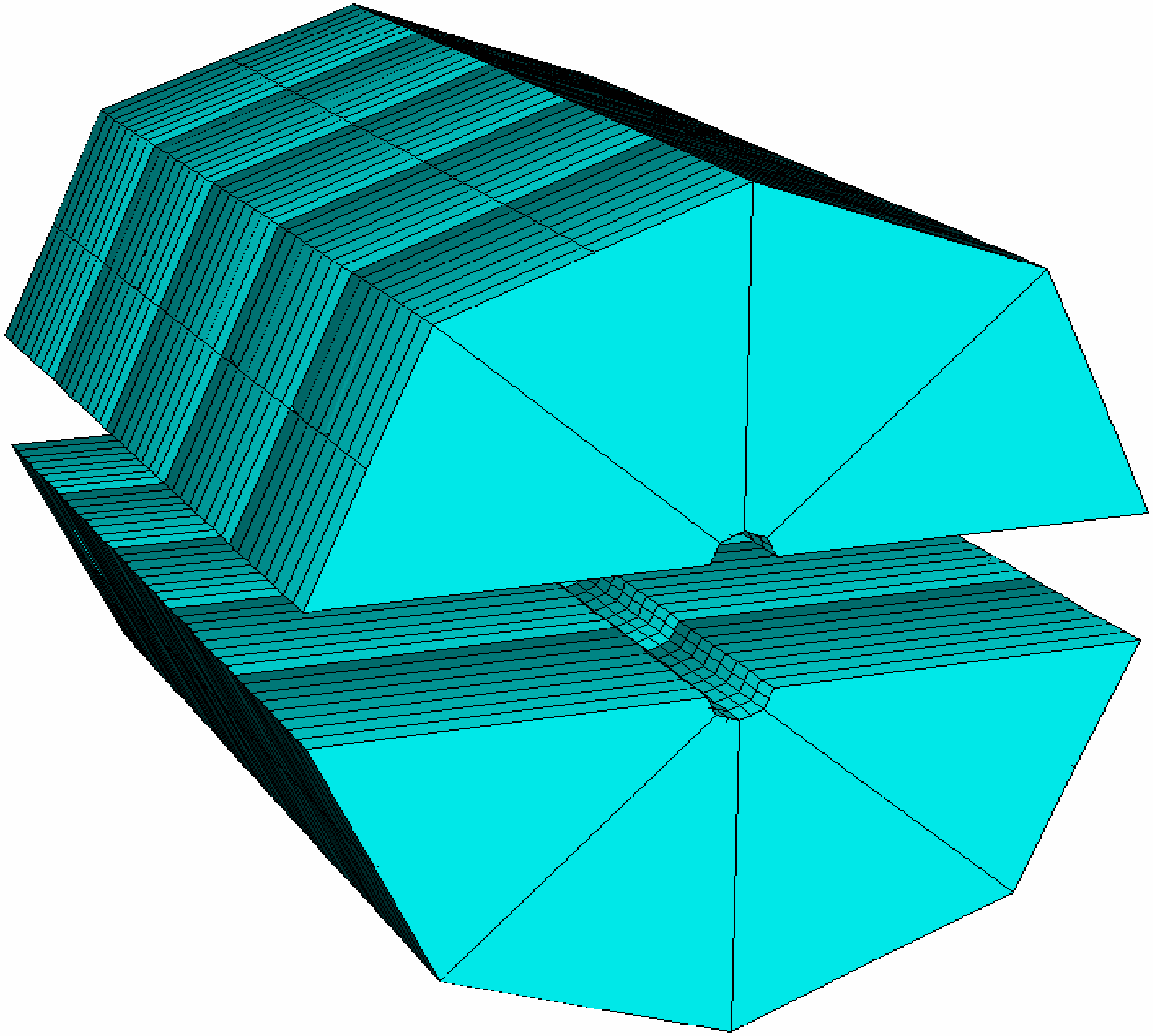
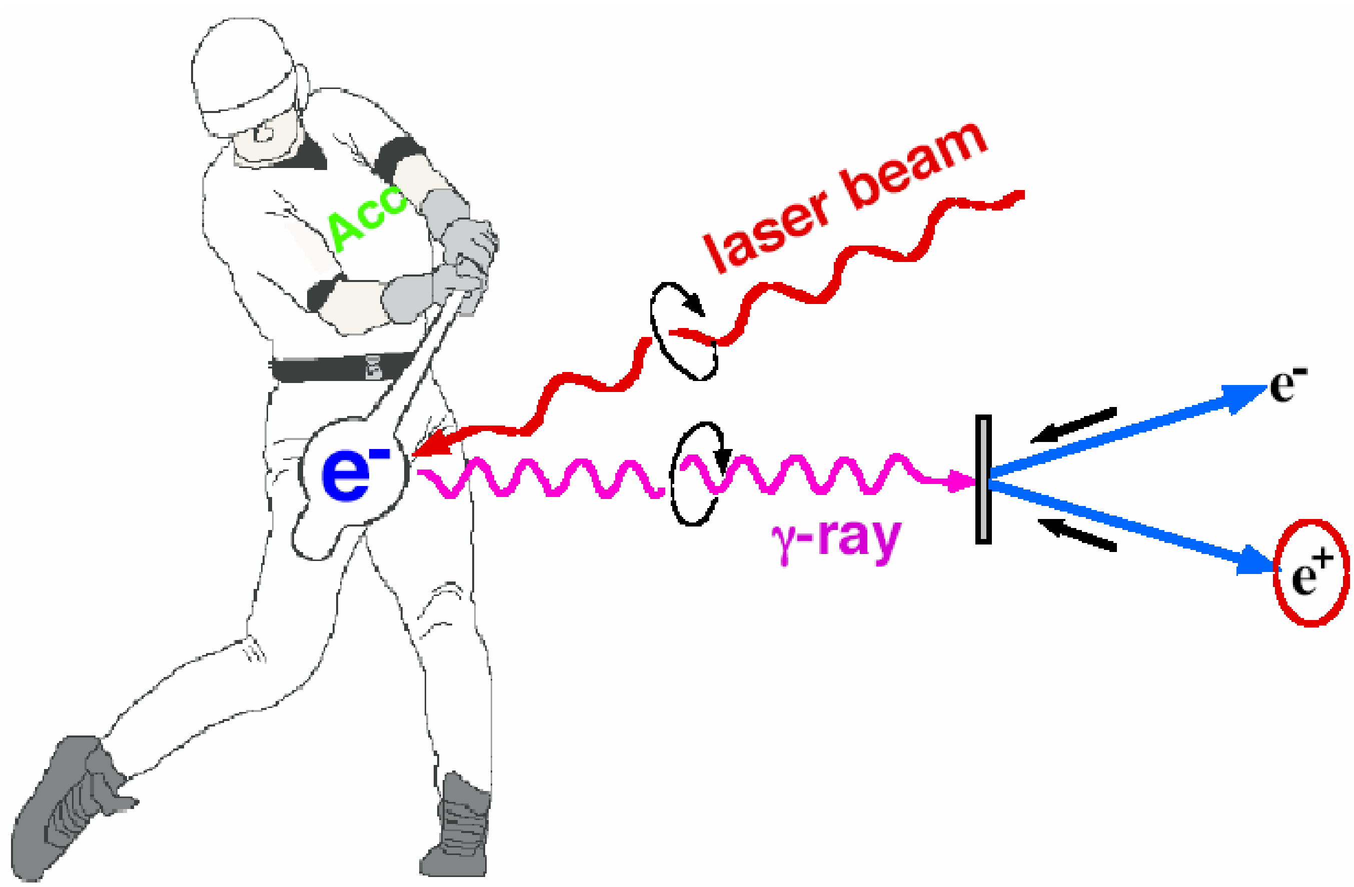
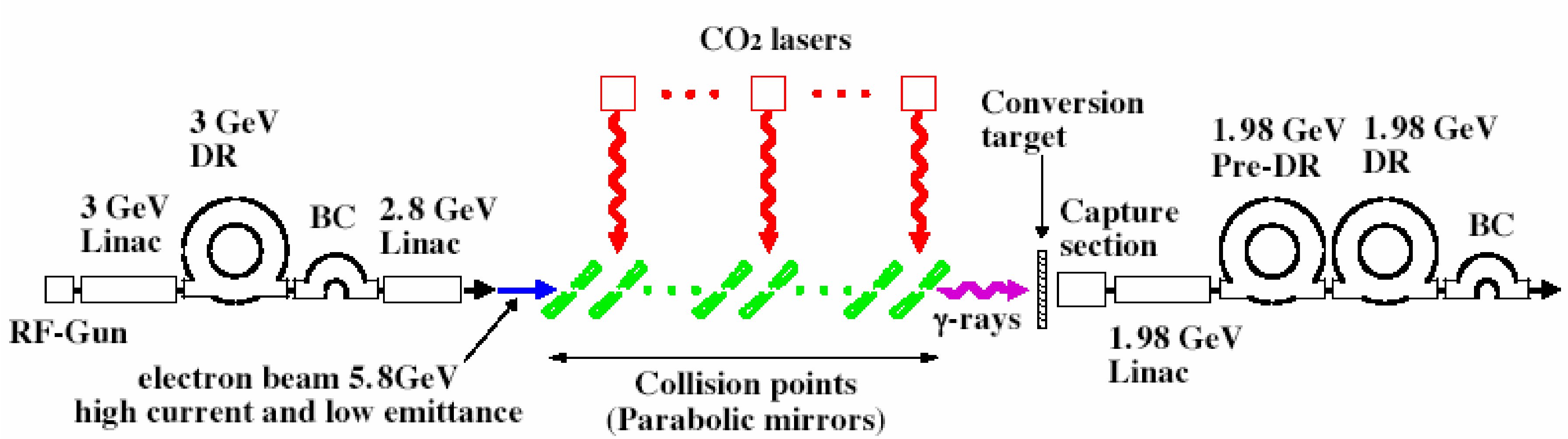


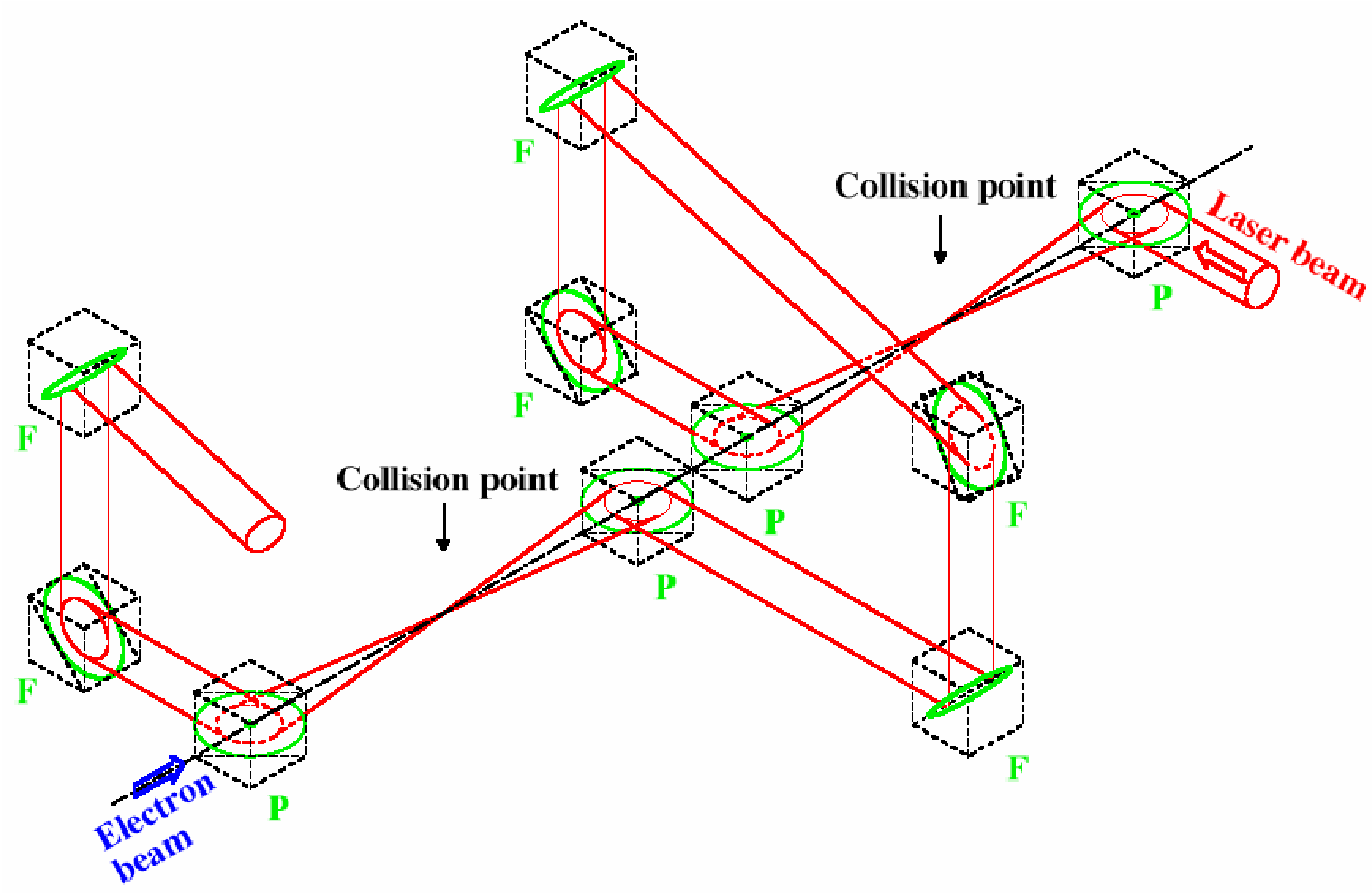
Compton Backscattering based Positron Source



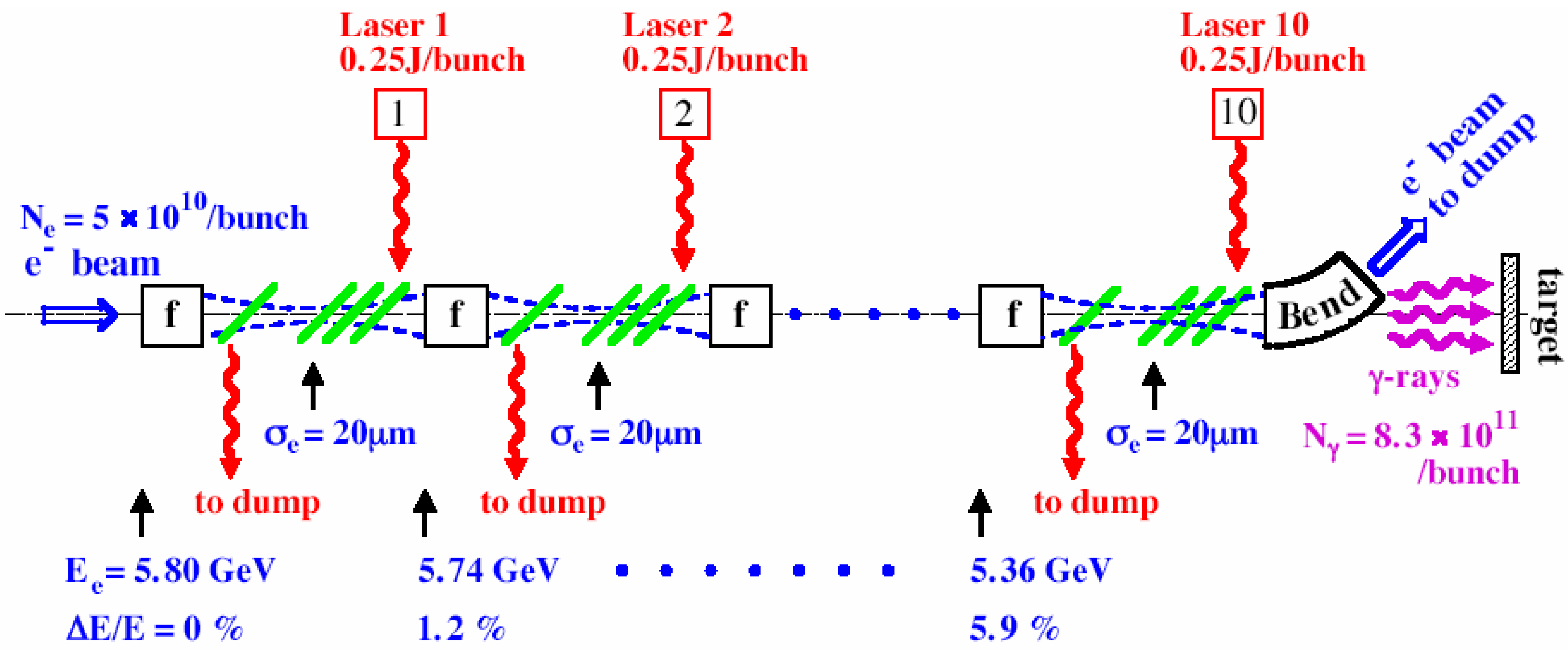
GLC Polarized Positron Source Design



Multi Collision Point Layout



GLC Collision Region



10 collision sections, with 20 collision points each:

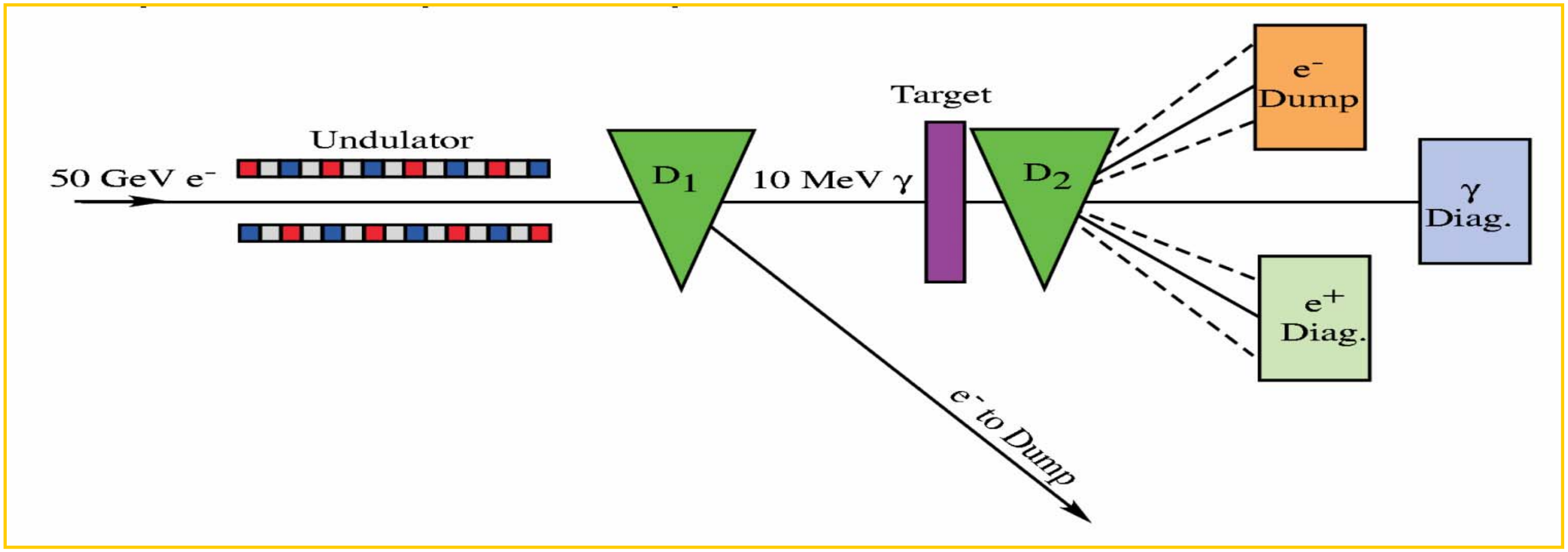
200 collision points

E-166 Demonstration Experiment for a Polarized Positron Source

About 47 members from 17 institutions:

Brunel, CERN, Cornell, DESY, Daresbury, Durham, Jefferson, Humboldt, KEK, Princeton, South Carolina, SLAC, Tel Aviv, Tokyo M.U., Tennessee, Wasada, Yerevan

E-166 Demonstration Experiment for a Polarized Positron Source

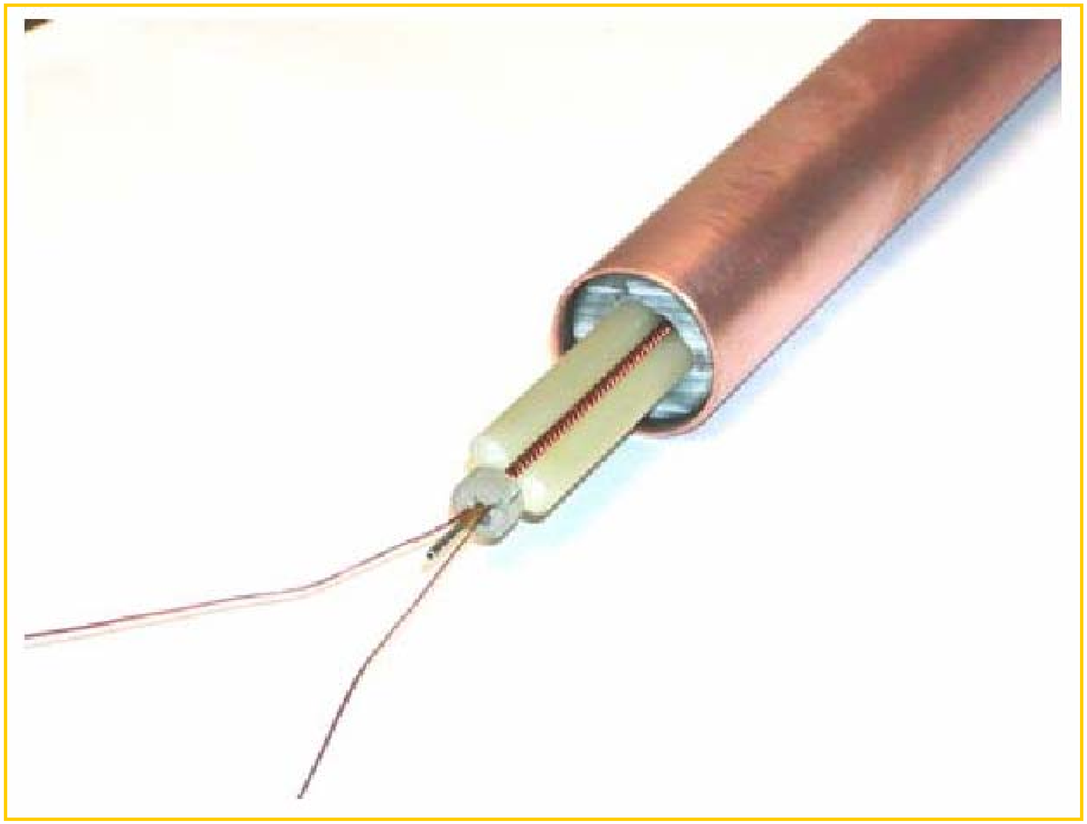


- Final Focus Test Beam (FFTB) at SLAC with 50 GeV Electrons.
- 1 m long helical undulator produces circular polarized radiation of up to 10 MeV.

Undulator Parameter for Polarized Positron Source

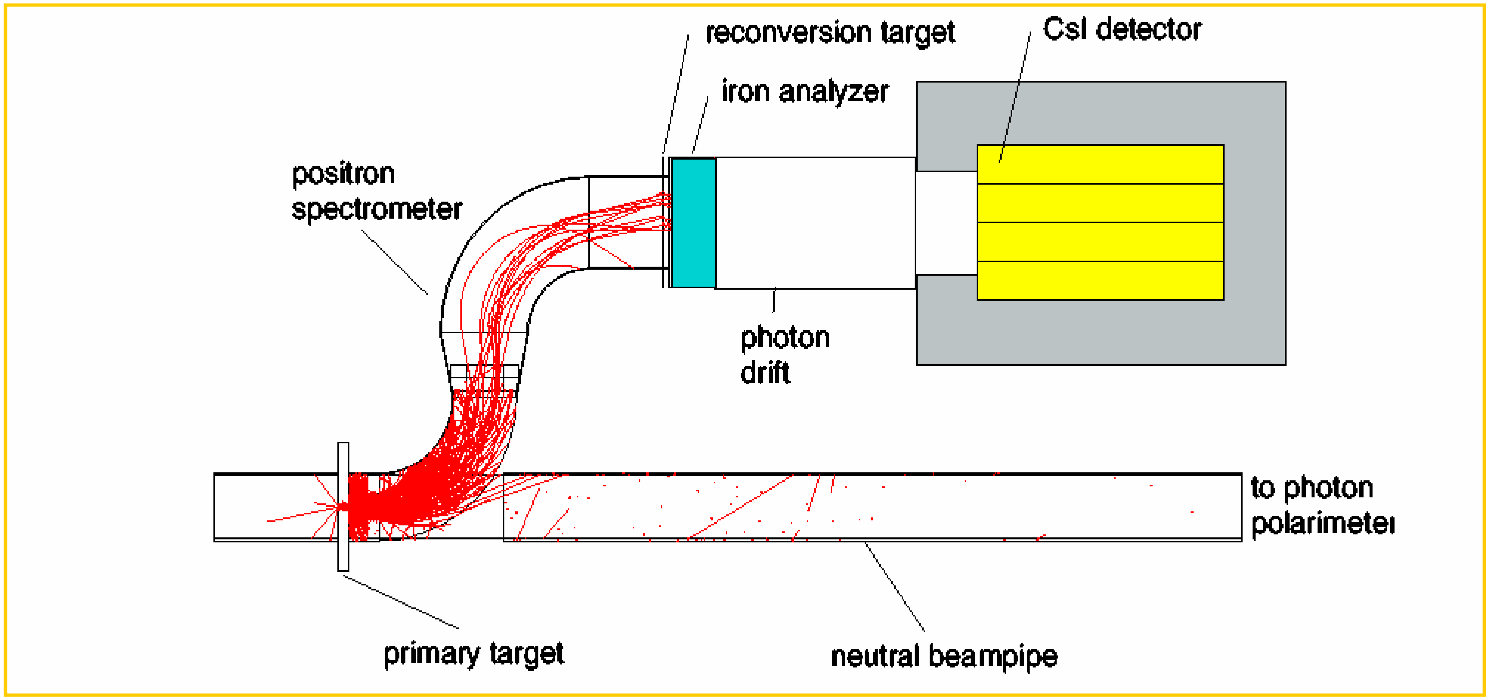
Parameter	TESLA	E-166
Length	~150 m	1 m
Beam	200 GeV	50 GeV
Period	14 mm	2.4 mm
B-field	0.7 T	0.76 T
Energy of first Harmonic	20 MeV	9.6 MeV
Positrons/bunch	$3 \cdot 10^{10}$	$2 \cdot 10^{7}$

Pulsed Undulator for E-166



- Inner diameter 0.89 mm
- Magnetic field: 0.76 T
- Pulsed current: 2.3 kA
- Rate 30 Hz

E-166 Demonstration Experiment for a Polarized Positron Source

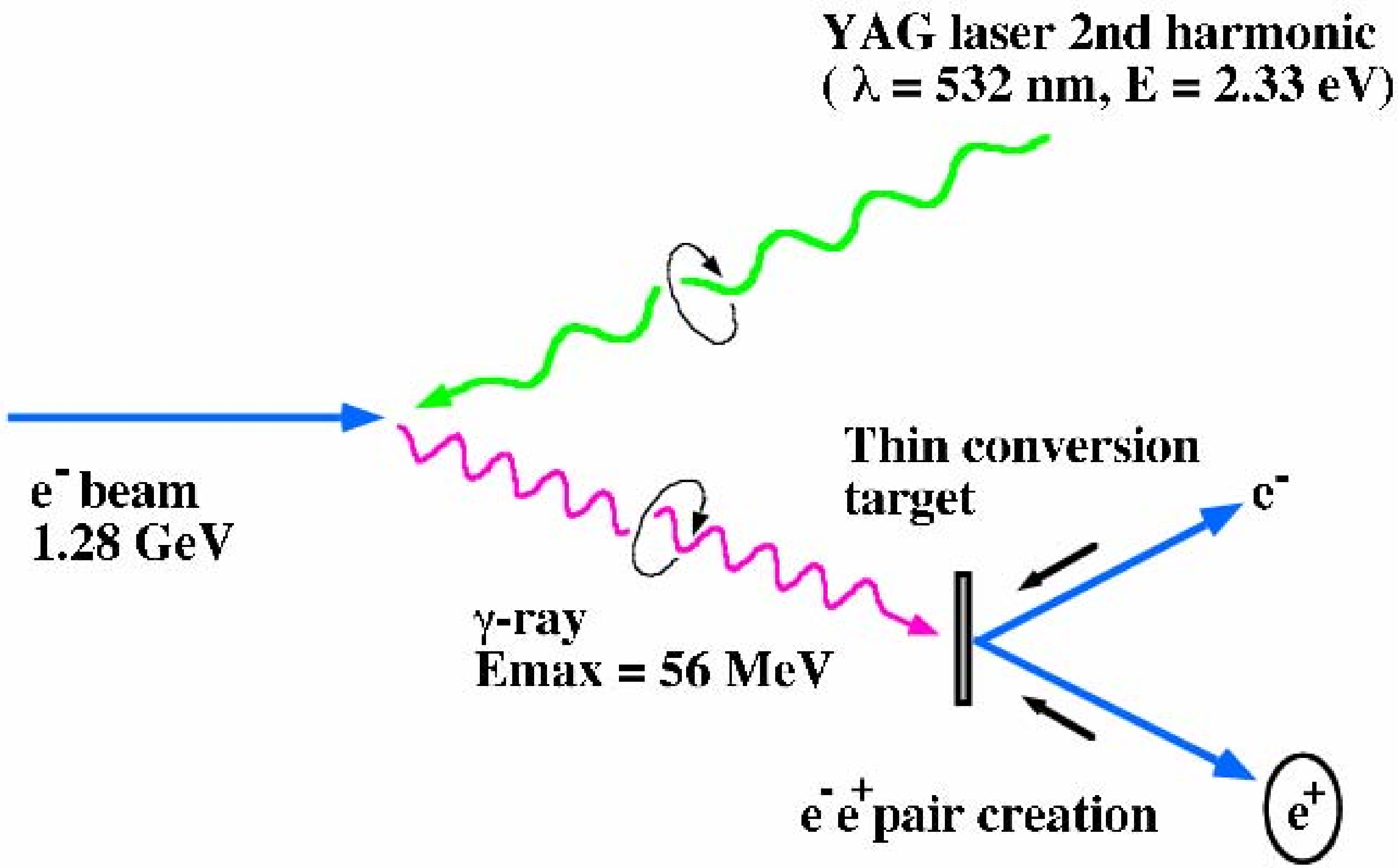


- Conversion of photons to positrons in 0.5 X_0 Ti-target
- Measurement of polarization of photons and positrons by Compton transmission method
- Expected polarization ~50%

E-166 Demonstration Experiment for a Polarized Positron Source

- E166 is a demonstration of production of polarized positrons for future linear colliders
- Uses the 50 GeV FFTB at SLAC
- Approved by SLAC in June 2003
- All components or prototypes work properly
- Installation of total experiment in FFTB tunnel in August 2004
- First data taking run in October 2004
- Second data taking in February 2005

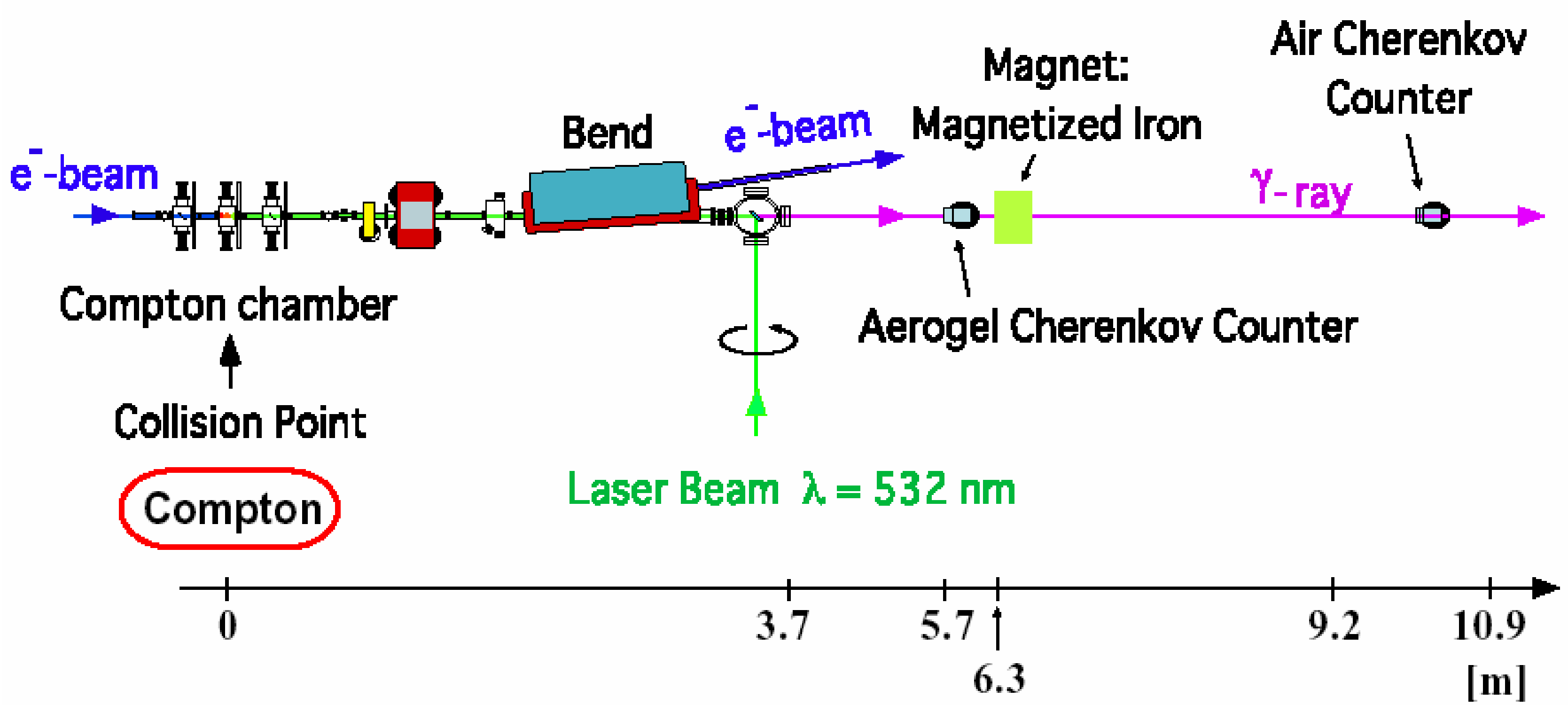
Experiment@KEK



Experiment@KEK

γ-ray: production, detection, and polarimetry

at ATF Extraction line



Experiment@KEK

1.) Production of polarized γ's and polarized e^+

- pol. γ: finished 2002
- pol e^+: underway

2.) Polarimetry

- polarimetry of short pulse & high intensity γ rays established
- same method applicable for polarized positrons

Acknowledgement

I would like to thank John Sheppard (SLAC), Tsunehiko Omori (KEK) and Duncan Scott (Daresbury) for providing figures and information.