Aspects of Radiation Level at the ILC Positron Source

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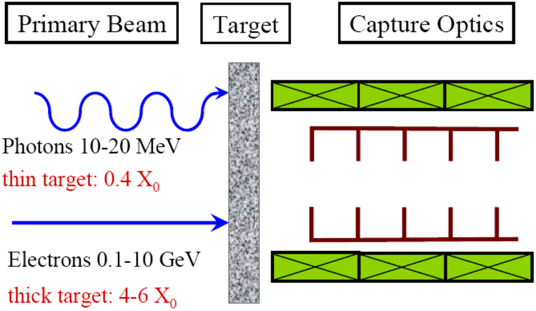
- Motivation
- Scheme of positron source
- Comparison of undulator-based and conventional positron sources
- Outlook

Positron Production

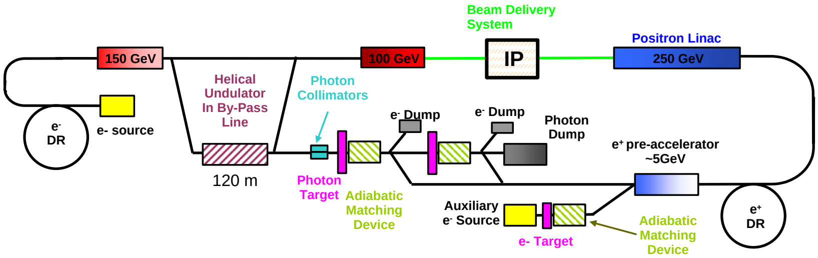


Conventional Method

Photon production

- planar undulator (unpolarized γ)
- helical undulator (circular polarized γ)
- Compton back scattering (circular polarized γ)

Schematic Overview of Undulator Based Positron Source



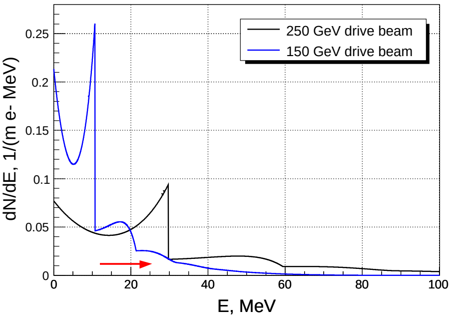
Motivation:

FLUKA studies to estimate:

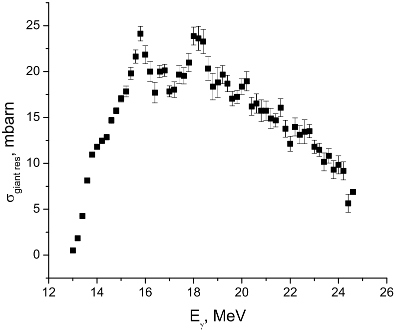
- radiation level
  - target survival
  - target remote handling
- energy deposition

Energy distribution of undulator photons

Energy Distributions of γ



Neutron Production: Cross Section of Giant Dipole Resonance in ^{46}Ti



Source Geometry and Primary Beam

Primary Beams

	conv.	undul. I	undul. II
E_{e^-}, GeV	6.2	150	250

- Beam radius of 0.35 mm
- No beam divergence

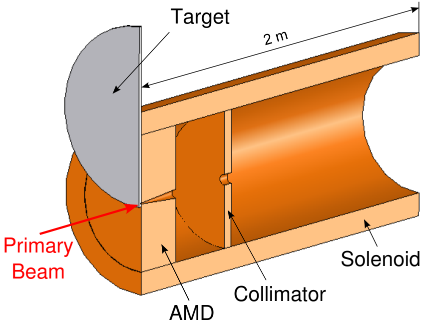
Target

	conv.	undul.
Thickness	4.5 X_0 (1.54 cm)	0.4 X_0 (1.42 cm)
Compounds	W 75.0 % Re 25.0 %	Ti 92.5 % Al 5.0 % Sn 2.5 %

Capture Section (Copper)

- Adiabatic Matching Device (AMD)
- Solenoid
- Collimator

Source Model



Magnetic Field:

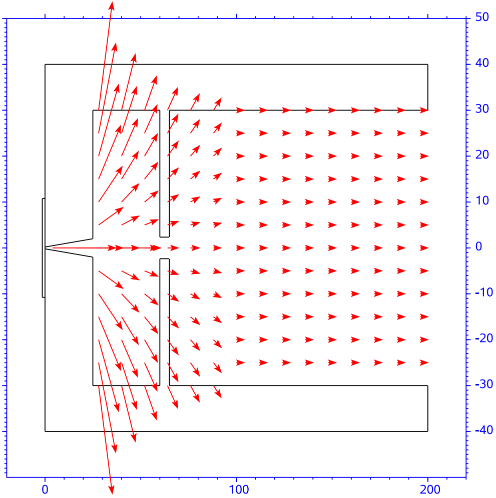
Adiabatic Matching Device

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

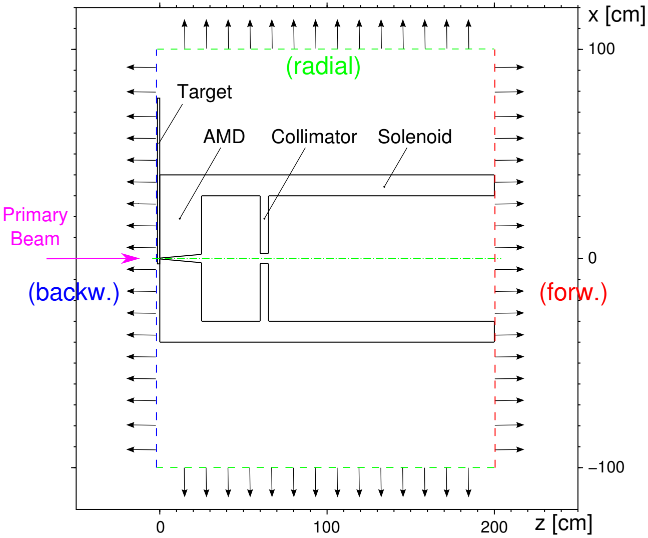
Initial field B_i	6 T
Final field B_f	0.22 T
Field length L	82.2 cm
Taper parameter g	30 m^{-1}

Solenoid field 0.22 T

No electric field!

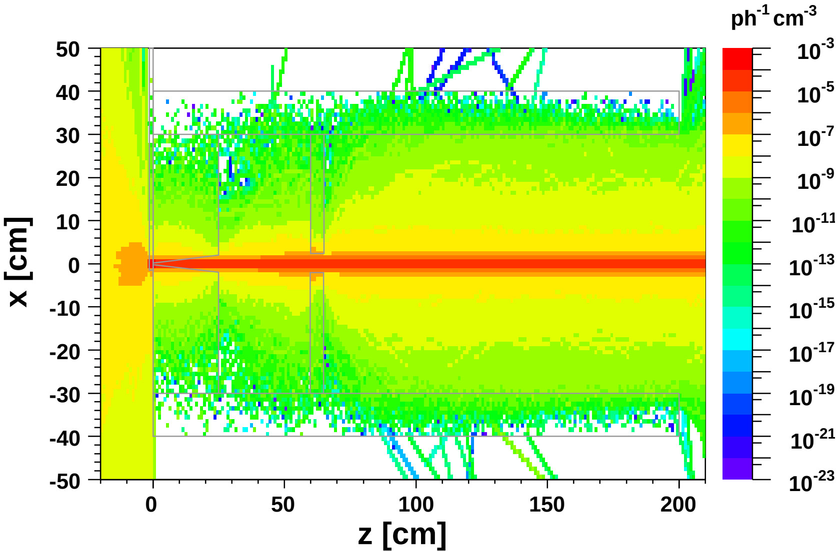


Definition of Calculated Fluxes



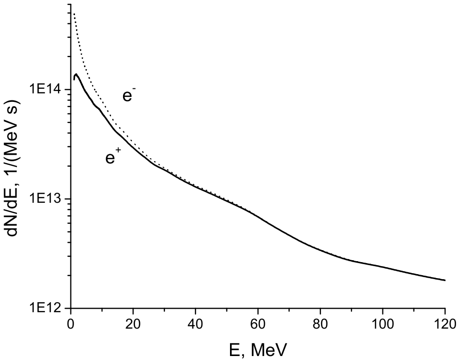
Positron density

Undulator Based Source (150 GeV)

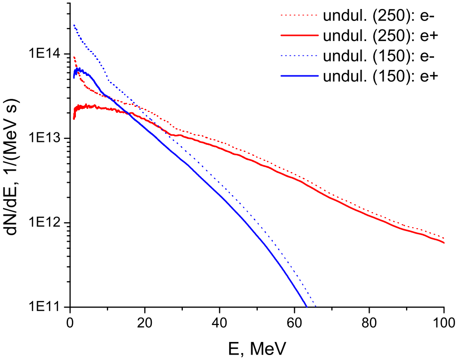


Energy Distributions of Electrons and Positrons

Conventional Source

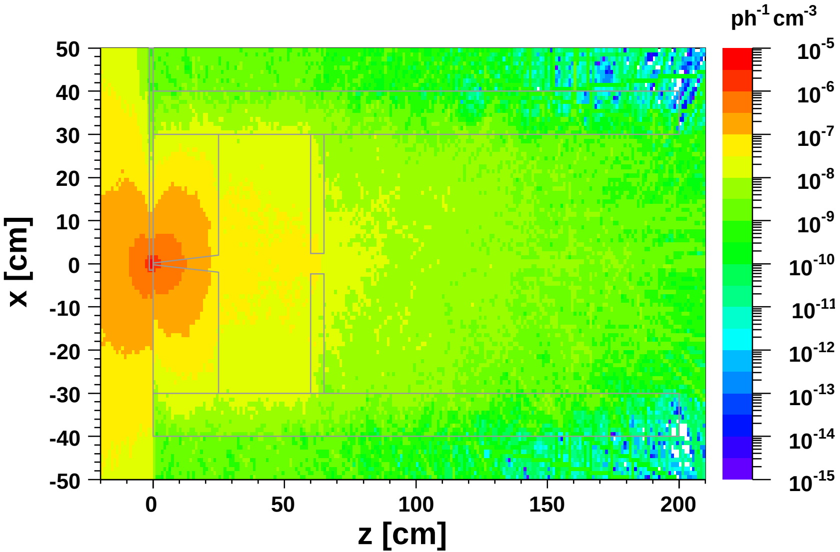


Undulator Based Sources



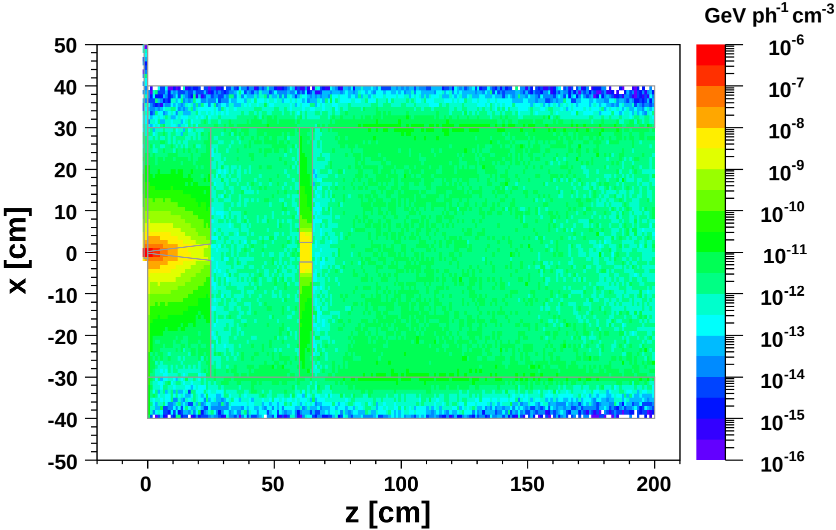
Neutron density

Undulator Based Source (150 GeV)



Deposited energy density

Undulator Based Source (150 GeV)



Heat Loading and Source Part Activation

Source type	conv.	undul. I	undul. II
Primary electron beam energy, GeV	6.2	150	250
Required number of positrons, e^+/s	2.82E+14 (2E+10 e^+/bunch)		
Positron capture efficiency, %	11.5	35	
Required number of primary electrons, e^-/s	5.04E+14	2.82E+14	
Required undulator length, m	–	115.53	38.22
Primary beam power, kW	499.74	160.99	147.93
Energy deposited in target, %	13.26	7.57	4.38
Energy deposited in capture section, %	28.25	6.62	8.58
Photon beam power (forw.), %	39.42	82.73	81.56
Electron beam power (forw.), %	9.36	1.53	2.86
Positron beam power (forw.), %	9.34	0.94	2.35
Number of neutrons, 1/s	2.75E+14	5.42E+13	3.55E+13
Source activation (after 5000 h), GBq	274646	17033	17347

Source part activation and dose rates

Undulator Based Source (150 GeV)

	A_{sat} GBq	A_{5000h} GBq	$\dot{D}_{5000h}$ mSv/h	$\dot{D}_{+1h}$ mSv/h	$\dot{D}_{+1d}$ mSv/h	$\dot{D}_{+1w}$ mSv/h
Target	8165.0	6524.2	828.1	755.3	427.4	322.4
AMD	8633.7	8401.2	185.3	33.4	8.7	0.3
Collimator	713.2	708.3	13.2	1.3	0.3	<0.1
Solenoid	1405.1	1399.6	4.0	3.2	0.9	<0.1
	18916.8	17033.3	1030.5	793.5	437.3	322.8

Notes:

- 50% chance of survival is for exposure of 3.5 Sv
- Annual occupational dose limit is of 20 mSv/y
- Acceptable level to allow restricted work is 0.1 mSv/h

Shutdown after 5000 h irradiation

- Reduction of dose rate by a factor of 10^4 is required
- 93% contribution in dose rate $\dot{D}_{+1w}$ by ^{46}Sc with $T_{1/2}$ = 84 d
- 1.1 MeV γ is radiated during decay of ^{46}Sc
- 90 cm of concrete or 15 cm of lead shielding is required

Outlook

- Undulator-based and conventional positron sources have been compared (comparison based on Fluka calculations)
- Neutron fluxes and dose rates have been estimated
- Plan (next future):
  Acceleration of positrons downstream of AMD will be taken into account
- Tool to study the radiation level at the positron source is available