Energy Deposition in Flux Concentrator by Undulator Photons at 250 GeV Center-of-Mass Energy

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Universität Hamburg

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LINEAR COLLIDER COLLABORATION

Outline

- Source parameters with 1312 bunches/pulse.
- Issue of high PEDD in Flux Concentrator (FC).
- PEDD in FC for
  - compact 125 GeV e^- dogleg;
  - different target thicknesses;
  - photon collimator with different aperture radii;
  - different apertures of FC.
- Yield vs undulator K value
- Impact of bigger space between FC and target
- Summary

Source Parameters (1312 Bunches/Pulse, 5 Hz, 14.8 mm Target)

[A. Ushakov, S. Riemann, POSIPOL2016]

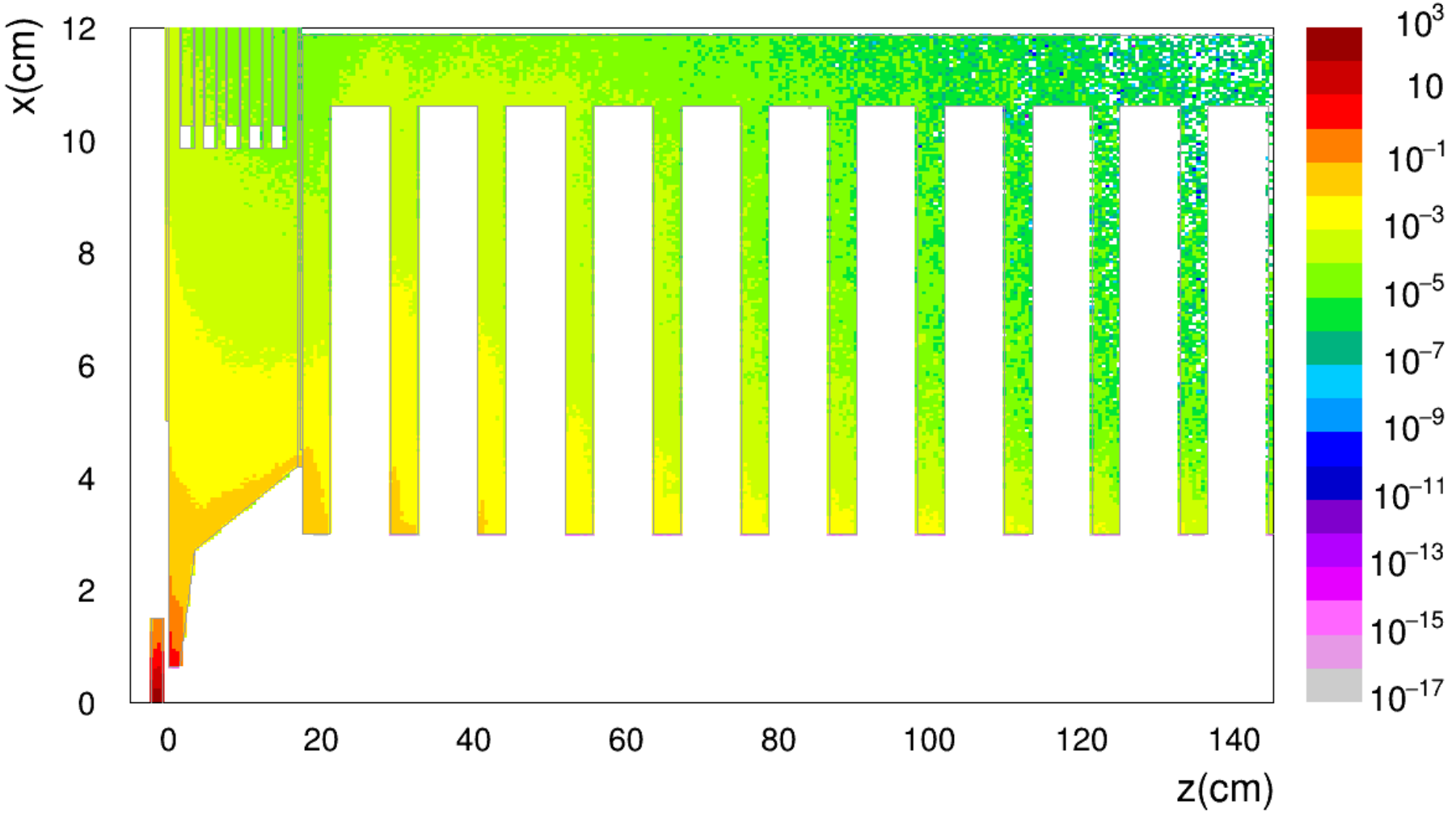
		125		150		175		250	
Electron beam energy	GeV								
Capture field type		decel.	accel.	decel.	accel.	decel.	accel.	decel.	accel.
Undulator active magnet length	m	231	>231			147			
Undulator K		0.85	>0.92	0.8	**0.92**	0.66	0.73	**0.45**	0.47
Photon yield per 1m of undulator	ph/(e- m)	1.70	-	1.52	**1.96**	1.07	1.29	**0.52**	0.56
Photon yield	ph/e-	392.7	-	223.9	**287.5**	157.3	189.5	**76.1**	82.8
Photon energy (1st harmonic)	MeV	**7.5**	-	11.3	10.1	17.6	16.5	**42.9**	42.3
Average photon energy	MeV	**7.3**	-	10.4	10.7	13.7	13.9	26.8	**26.9**
Average photon beam power	kW	**60.2**	-	48.8	64.6	45.2	55.3	**42.9**	46.8
Electron energy loss in undulator	GeV	2.9	-	2.3	**3.1**	2.2	2.6	**2.0**	2.2
Energy deposition per photon	MeV	**0.7**	-	0.8	0.8	1.0	1.0	**1.4**	1.4
Relative energy deposition	%	**9.0**	-	8.0	7.8	7.3	7.2	5.3	**5.2**
Average power deposited in target	kW	**5.4**	-	3.9	5.1	3.3	4.0	**2.3**	2.4
Photon bunch energy	J	9.2	-	7.4	**9.8**	6.9	8.4	**6.5**	7.1
Energy deposition per bunch	J	**0.83**	-	0.60	0.77	0.50	0.61	**0.35**	0.37
Space from middle of undul. to target	m	570	-			500			
Photon spot size on target (sigma)	mm	**1.72**	-	1.21	1.40	0.89	0.95	**0.50**	0.51
PEDD in target per bunch	J/g	**0.40**	-	0.49	0.54	0.66	0.72	1.19	**1.28**
PEDD in target per pulse	J/g	43.7	-	**41.0**	**50.3**	42.4	49.7	45.8	48.4
Polarization of captured positrons	%	30.7	-	29.4	31.6	30.8	**33.9**	**24.9**	30.1

Energy Deposition in FC and First Capture Cavities

125 GeV e^-, 1312 bunches/pulse, TDR dogleg

231 m undulator magnet length, $K = 0.85$, 1.48 cm Ti6Al4V target, $B^{FC}_{max} = 3.2$ T, 1.5 e^+/e^-

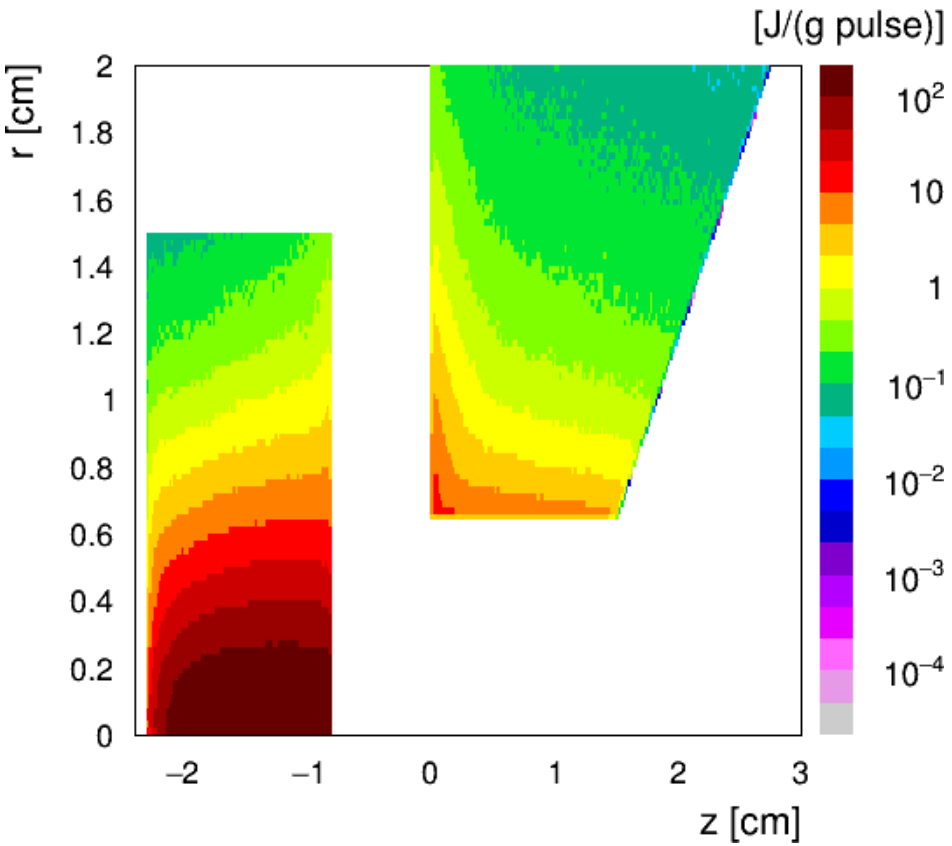
569.9 m distance from middle of undulator to target



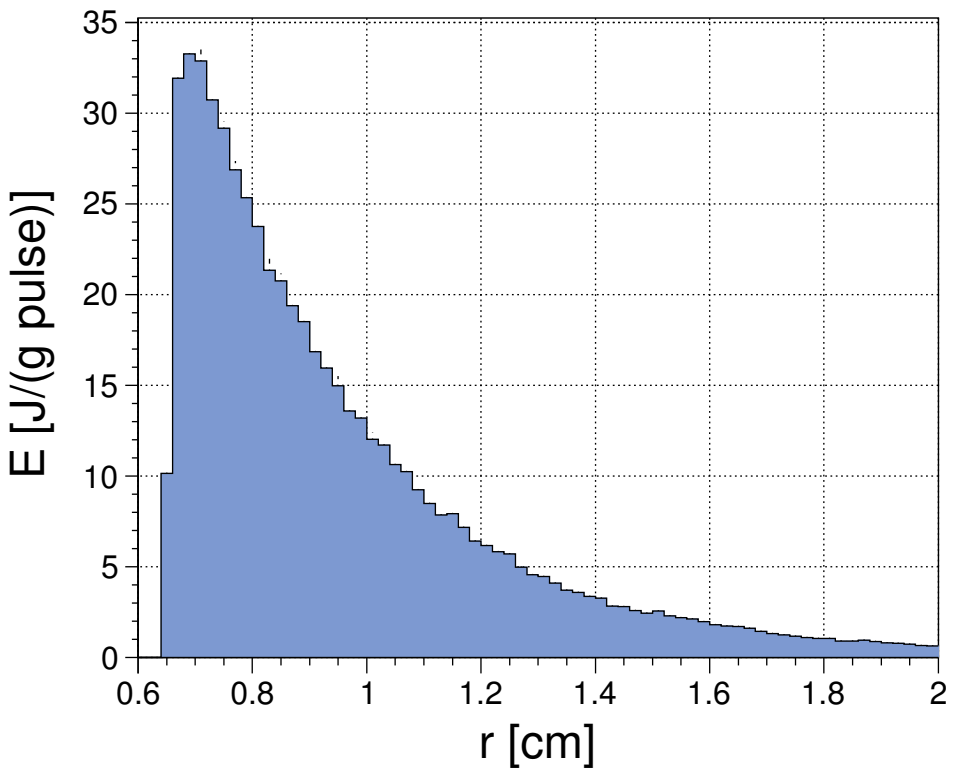
PEDD in FC

125 GeV e^-, 1312 bunches/pulse, 231 m undulator, $K = 0.85$, 14.8 mm target

Energy Deposition in Target* and FC



E vs r at z = 0.3 mm



* Target without rotation

PEDD = 43.7 J/(g pulse) in rotated target with 100 m/s

PEDD_{FC} = 33.3 J/(g pulse)

ΔT_{inst} = 86.4 K/pulse

PEDD(Cu) < 7 ÷ 12 J/g
[TESLA-FEL-2006-05 Report]

Compact 125 GeV Electron Dogleg

125 GeV e^-, 1312 bunches/pulse, 231 m undulator, $K = 0.85$, 14.8 mm target

Compact dog-leg for 125 GeV e^- beam designed by Okugi allows reduction up to 168.8 m undulator-to-target distance

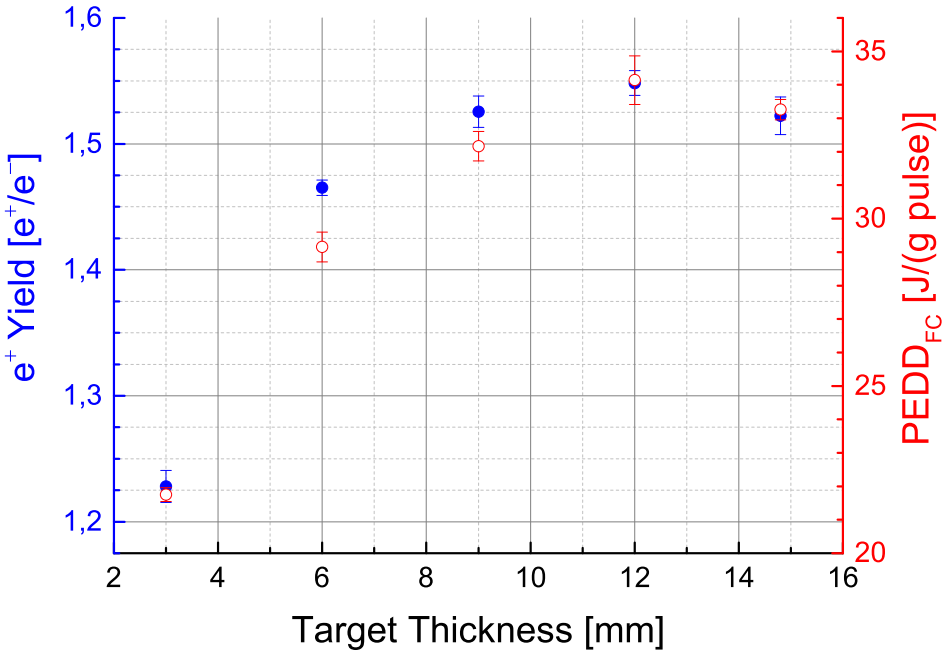
[https://agenda.linearcollider.org/event/7573/contributions/38619/attachments/31296/47039/PosiPol_okugi_20170316.pdf]

	TDR Dogleg	Compact Dogleg	Difference
Middle of undulator to target distance [m]	569.9	401.1	-168.8
rms photon spot size on target σ [mm]	1.7	1.2	-29.5%
Positron yield [e^+/e^-]	1.522	1.555	+2.1%
Average power in target [kW]	5.44	5.51	+1.2%
Average power in FC [kW]	2.96	2.55	-13.9%
PEDD in FC [J/(g pulse)]	33.3	29.3	-12.0%

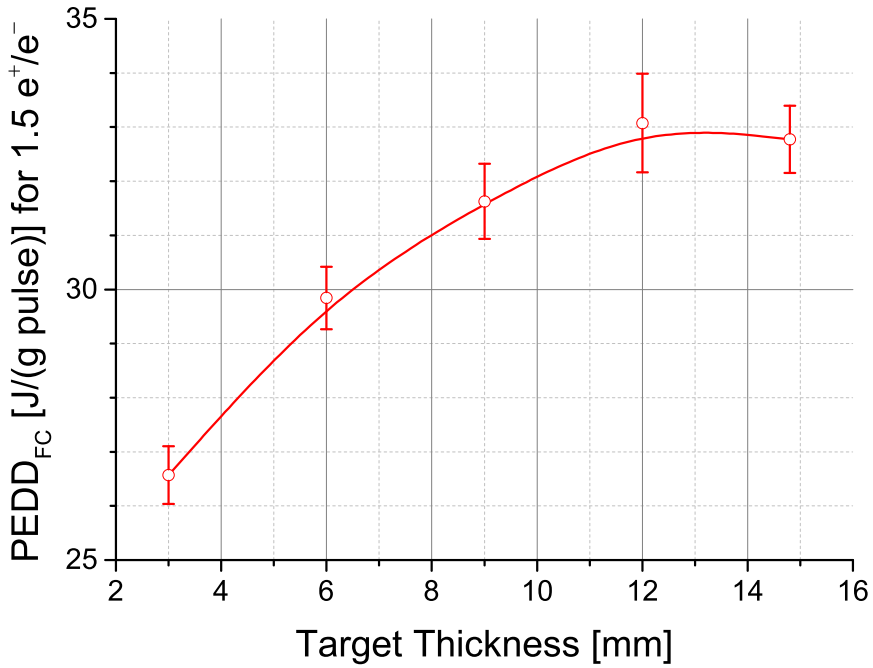
e^+ Yield and PEDD in FC vs Target Thickness

125 GeV e^-, 1312 bunches/pulse, $K = 0.85$, TDR dogleg

Fixed Undulator Length (231 m)



Varied Undulator Length (1.5 e^+/e^-)

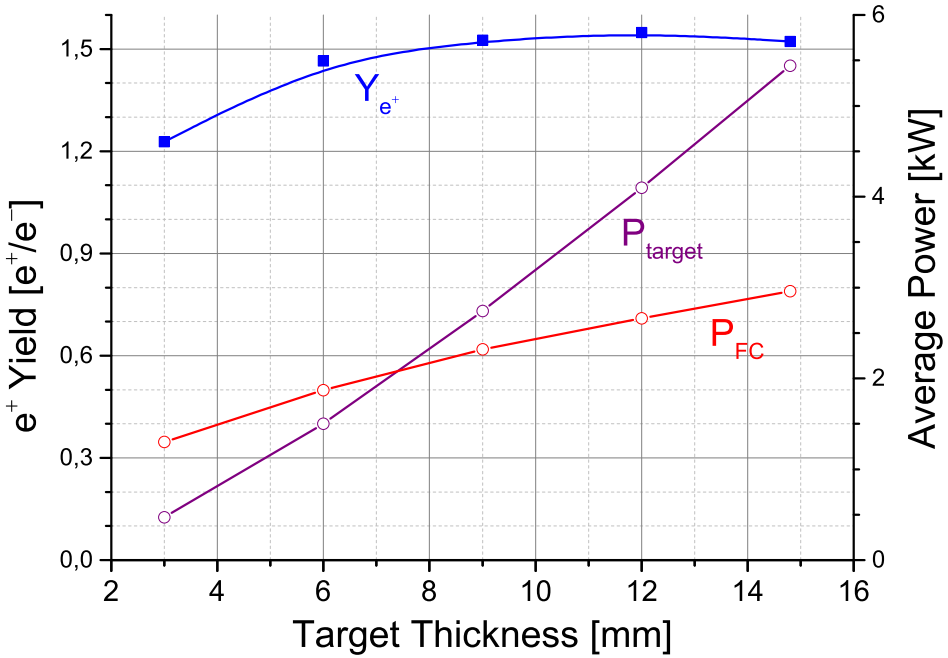


Using thinner target slightly reduces PEDD in FC:
$\approx$ 8% for thickness of 7 mm

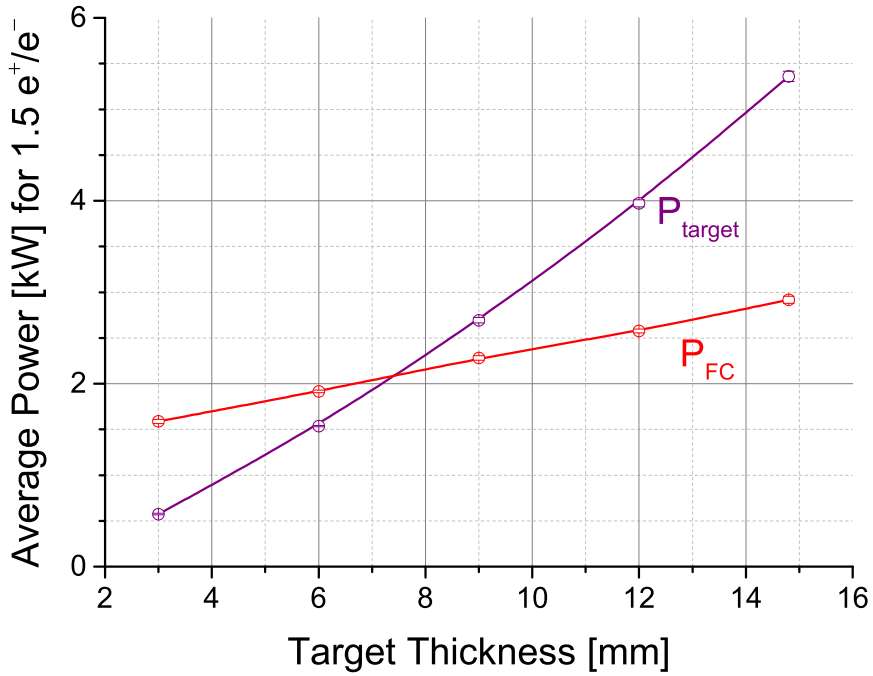
Average Power in Target and FC vs Target Thickness

125 GeV e^-, 1312 bunches/pulse, $K = 0.85$, TDR dogleg

Fixed Undulator Length (231 m)



Varied Undulator Length (1.5 e^+/e^-)



Reduction of target thickness reduces average power in target significantly

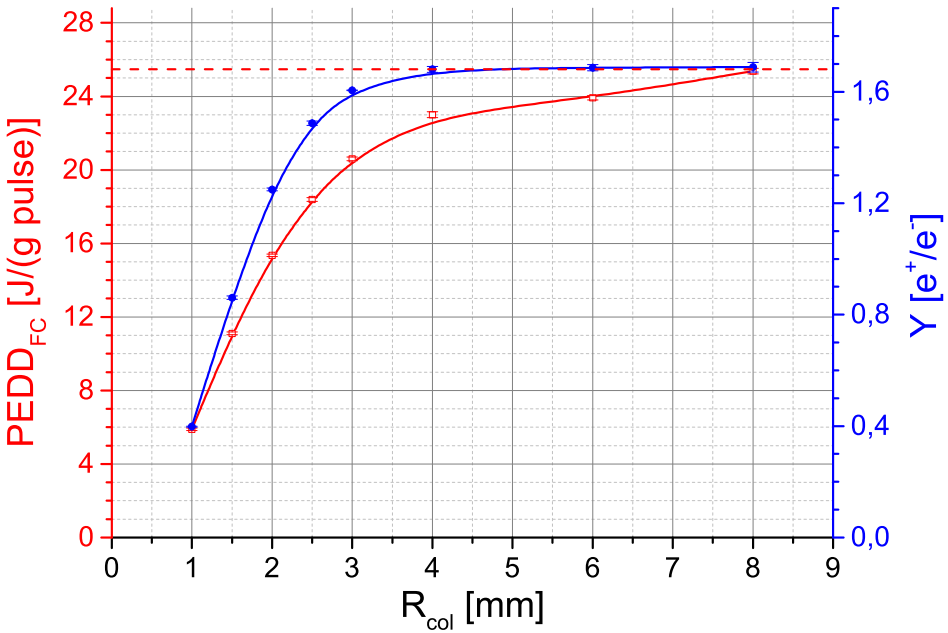
PEDD in FC vs Aperture Radius of Photon Collimator

128 GeV e^-, 1312 bunches/pulse, $K = 0.85$, compact dogleg, 7 mm target

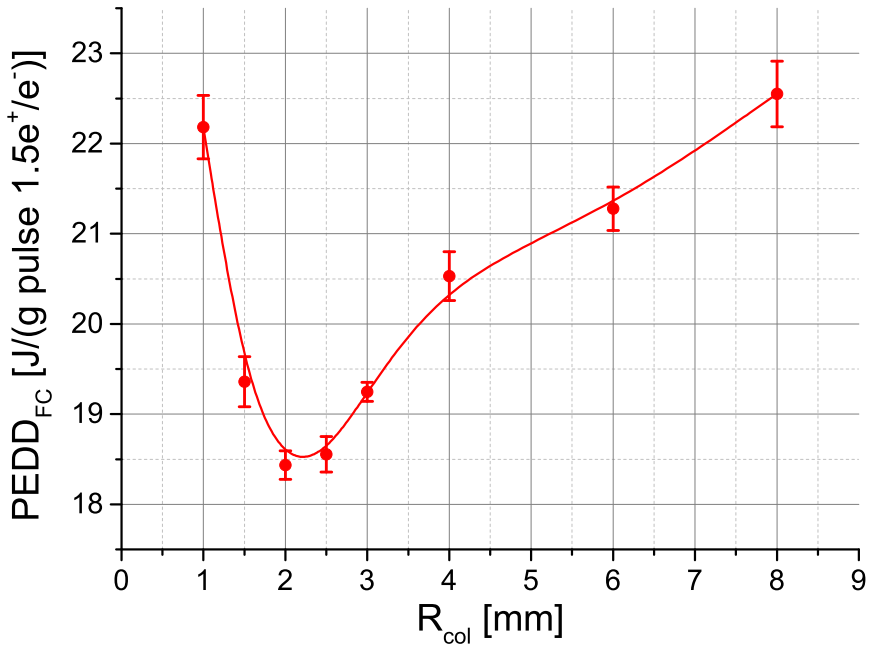
128 GeV e^- at the end of main linac (3 GeV energy losses in undulator)

Photon collimator is placed upstream the target

Fixed Undulator Length (231 m)



Varied Undulator Length (1.5 e^+/e^-)

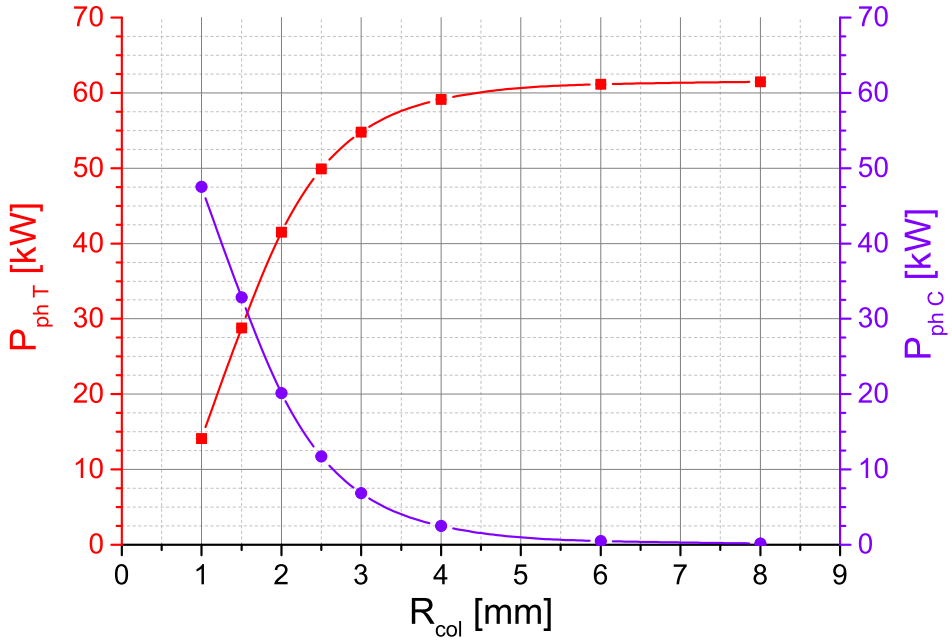


Collimator with aperture radius of 2.5 mm reduces PEDD in FC on 18%

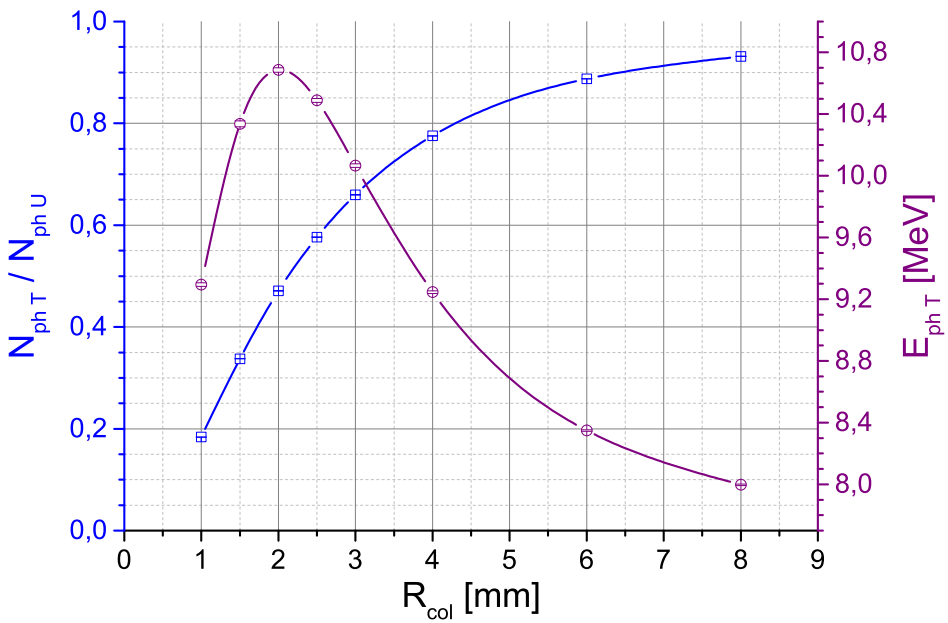
Photon Power Absorbed in Collimator and on Target

128 GeV e^-, 1312 bunches/pulse, $K = 0.85$, compact dogleg, 7 mm target

Photon Power on Target and Power Absorbed in Collimator



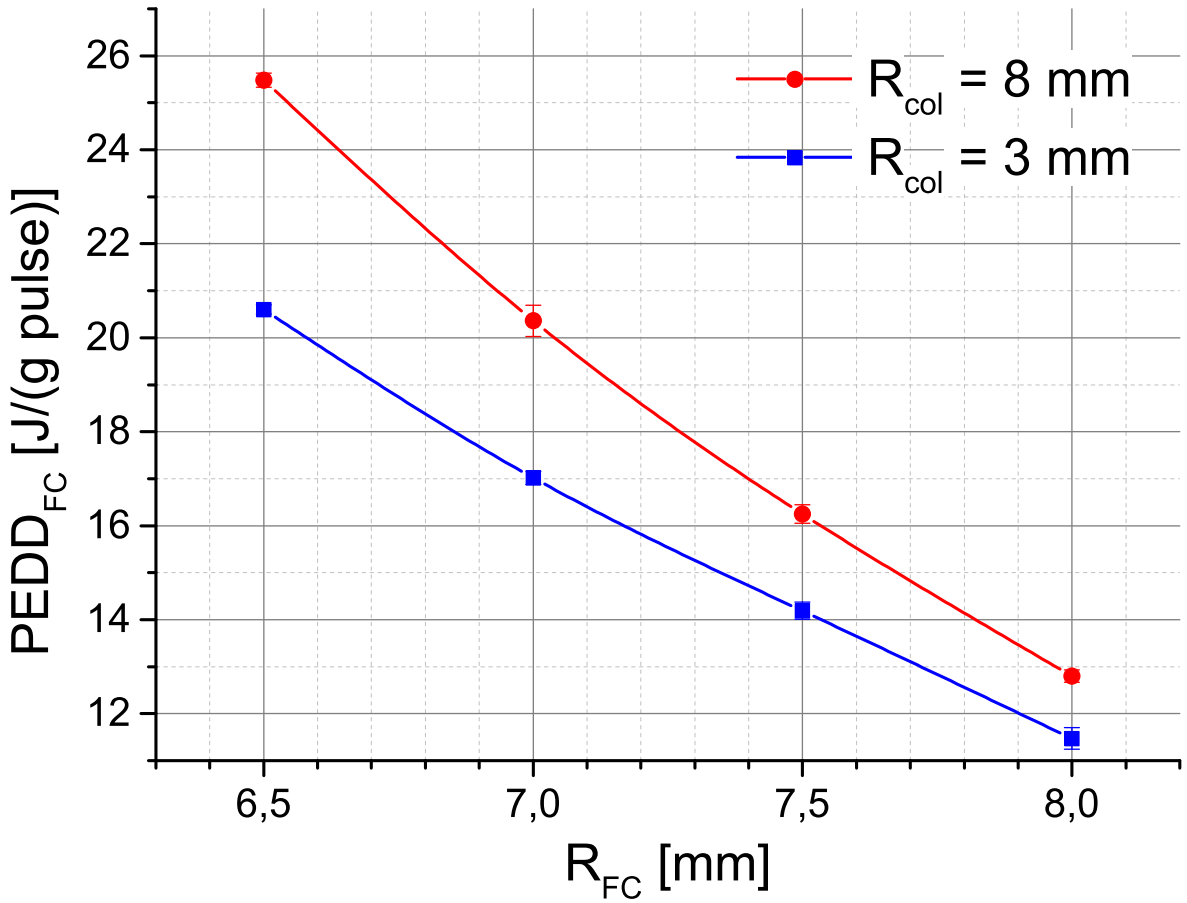
Fraction of Photons on Target and Average Photon Energy on Target



PEDD in FC vs Aperture Radius of FC

128 GeV e^-, 1312 bunches/pulse, $K = 0.85$, compact dogleg, 7 mm target

3.2 T peak field of FC was kept constant

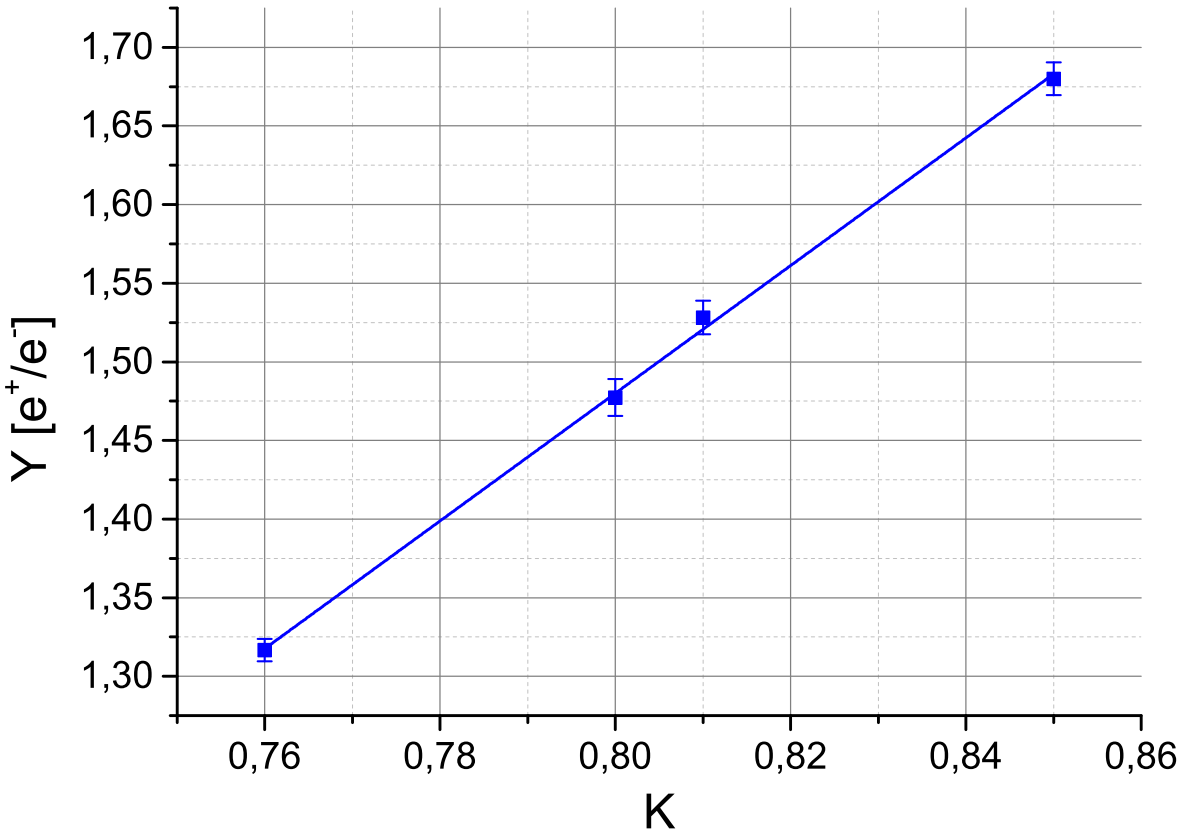


To reduce PEDD down to 12 J/g

FC aperture radius has to be increased from 6.5 mm to $\approx$ 8 mm

Positron Yield vs Undulator K Value

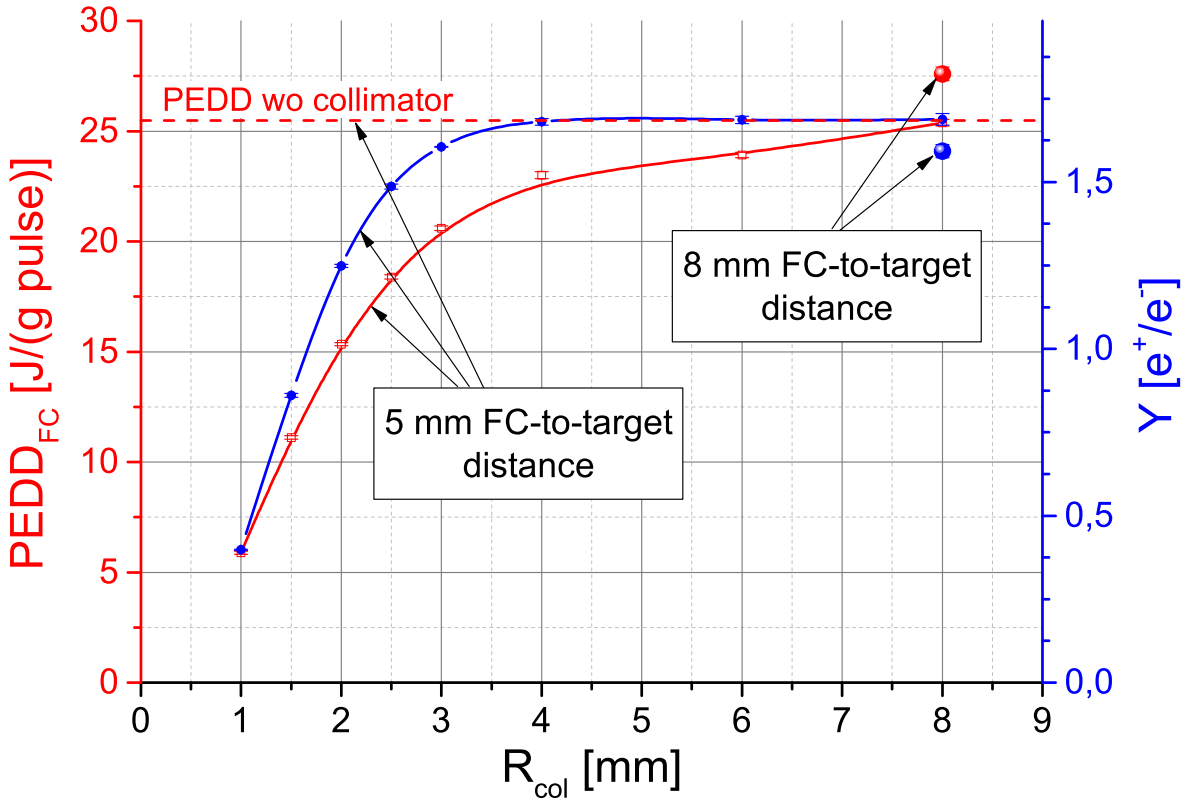
128 GeV e^-, 1312 bunches/pulse, compact dogleg, 7 mm target, $R_{col} > 4$ mm



$$Y(K = 0.805) = 1.5\ e^+/e^-$$

Yield and PEDD in FC for 8 mm FC-to-Target Distance

128 GeV e^-, 1312 bunches/pulse, compact dogleg, 7 mm target



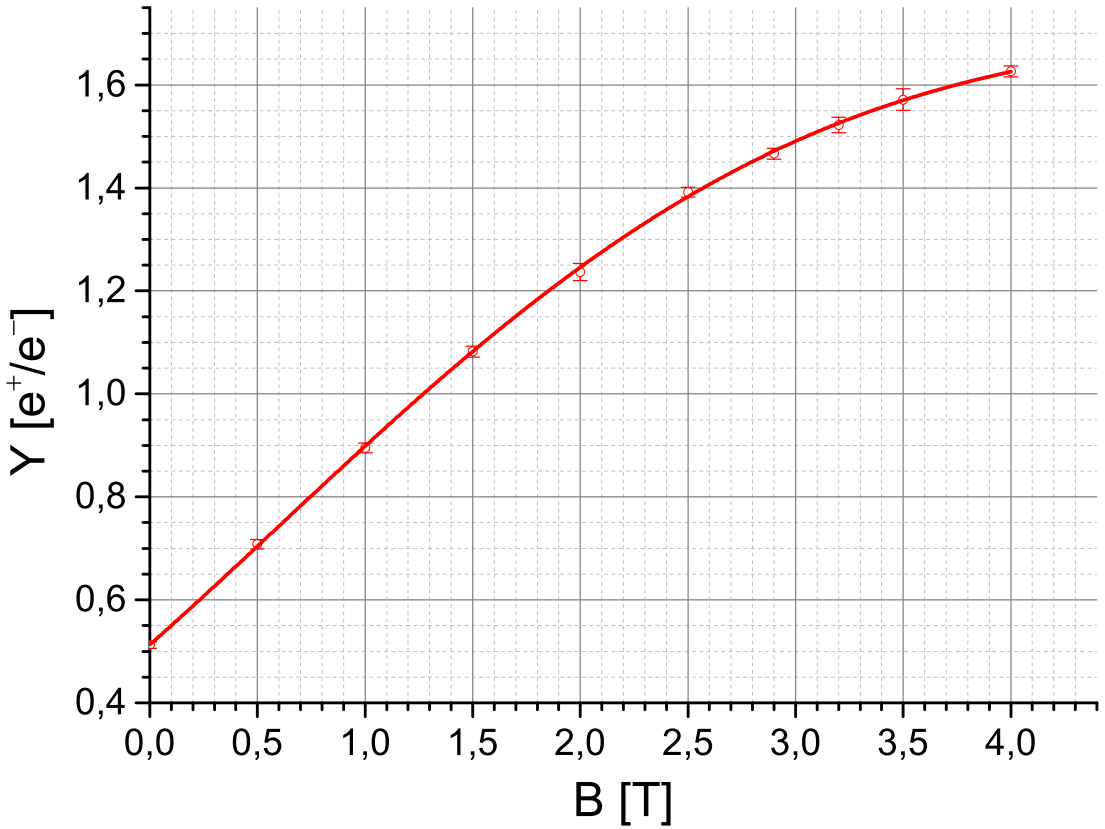
Change FC-to-target distance from 5 mm to 8 mm does not change PEDD in FC and positron yield significantly

Summary

- 33.3 J/(g pulse) PEDD in FC is too high for 125 GeV e^- beam energy, TDR e^- dogleg, 14.8 mm target thickness and 3.2 T flux concentrator with 6.5 mm aperture radius.
- Using compact e^- dogleg instead of TDR dogleg reduces PEDD to 29.3 J/(g pulse).
- Reduction of target thickness to 7 mm results in $\approx$ 8% lower PEDD.
- Increase of e^- beam energy at beginning of undulator to 128 GeV (energy losses in undulator are 3 GeV) and reduction of target thickness to 7 mm result in PEDD of 25.5 J/(g pulse).
- Applying of photon collimator upstream the target can reduce PEDD down to 18.5 J/(g pulse).
- To get PEDD $\approx$ 12 J/(g pulse) aperture of 3.2 T FC has to be increased from 6.5 mm to $\approx$ **8 mm**.

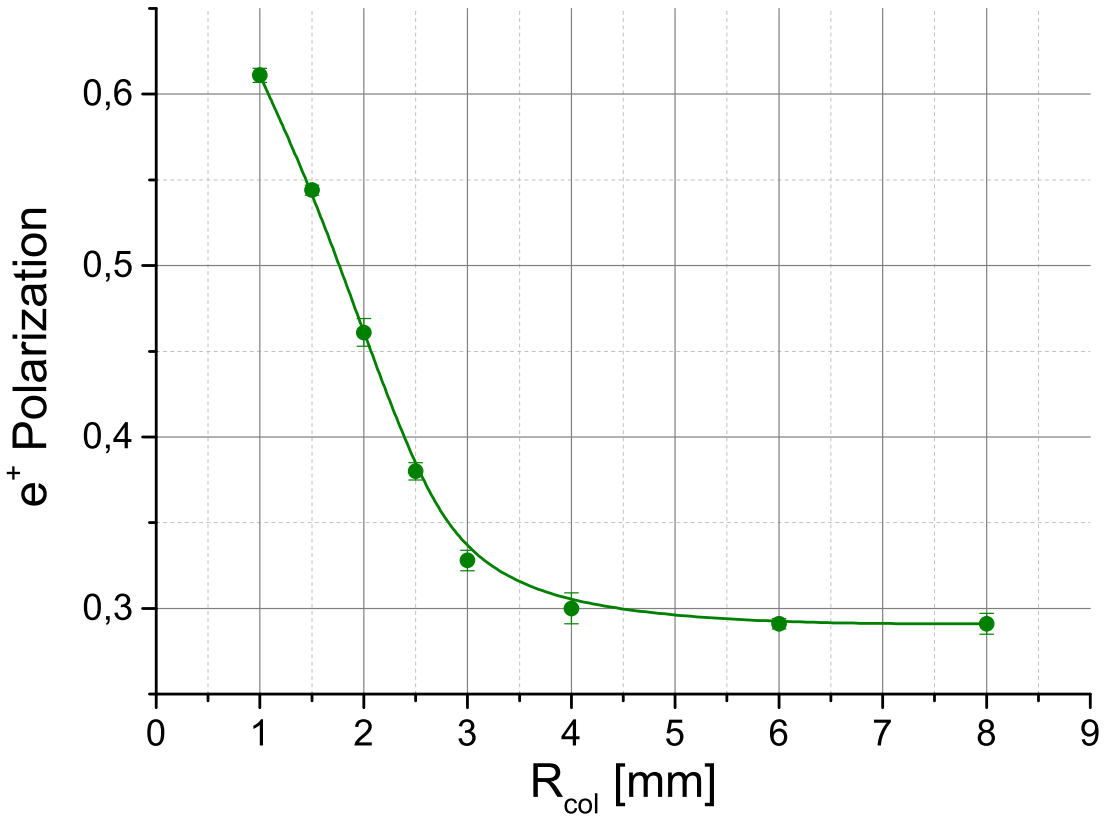
e^+ Yield vs Field of FC

125 GeV e^-, 231 m undulator, $K = 0.85$, TDR dogleg, 14.8 mm target, $R_{FC} = 6.5$ mm



e^+ Polarization vs Aperture Radius of FC

128 GeV e^-, 231 m undulator, $K = 0.85$, compact dogleg, 7 mm target



Note: $Y_{e^+} < 1.5\ e^+/e^-$ for $R_{col} \lesssim 2.7$ mm