Optimisation of the CLIC positron source

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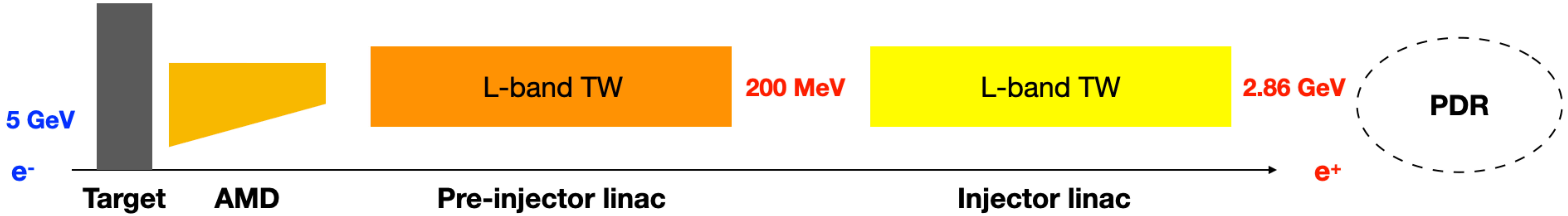
Abstract

In this report, we reoptimised the CLIC positron source at all collision energy stages. Simulation, optimisation algorithm and results were all improved compared with previous studies. Two different target schemes were studied and compared in terms of the advantages and disadvantages. The spot size of the injected electron beam was also optimised to achieve a compromise between large positron yields and safe energy deposition. The matching device for the capture of positrons was simulated and optimised with both improved analytic and realistic field maps. Conical aperture and front and rear gaps of the matching device were also considered for the first time. The optimised positron source is expected to have the lowest cost.

Introduction

- **CLIC positron source layout**
  - Electron gun and drive linac, **Target**, Adiabatic Matching Device (**AMD**), **Pre-injector** linac, **Injector** linac
- **Simulation tools**
  - Geant4, Fot, RF-Track, Opera®, Placet
- **Figures of merit**
  - Electron **beam power**: the lower the better
  - **Positron yield** accepted by PDR: the higher the better (when e- energy fixed)
  - Peak energy deposition density (**PEDD**) in target < 35 J/g
  - **Deposited power** in target: the lower the safer (reference limit: ~15 kW)

$$\text{yield}_{e+} = \frac{n_{e+}^{\text{produced}}}{n_{e-}^{\text{primary}}}$$



Target

- **Hybrid scheme** (Fig. 1)
  - Lower e⁺ yield (Fig. 2)
  - Potentially safer radiation and thermal load
  - Alternative scheme with radiation & thermal studies still in progress
- **Conventional scheme** (Fig. 3)
  - Higher e⁺ yield
  - Adopted in this study

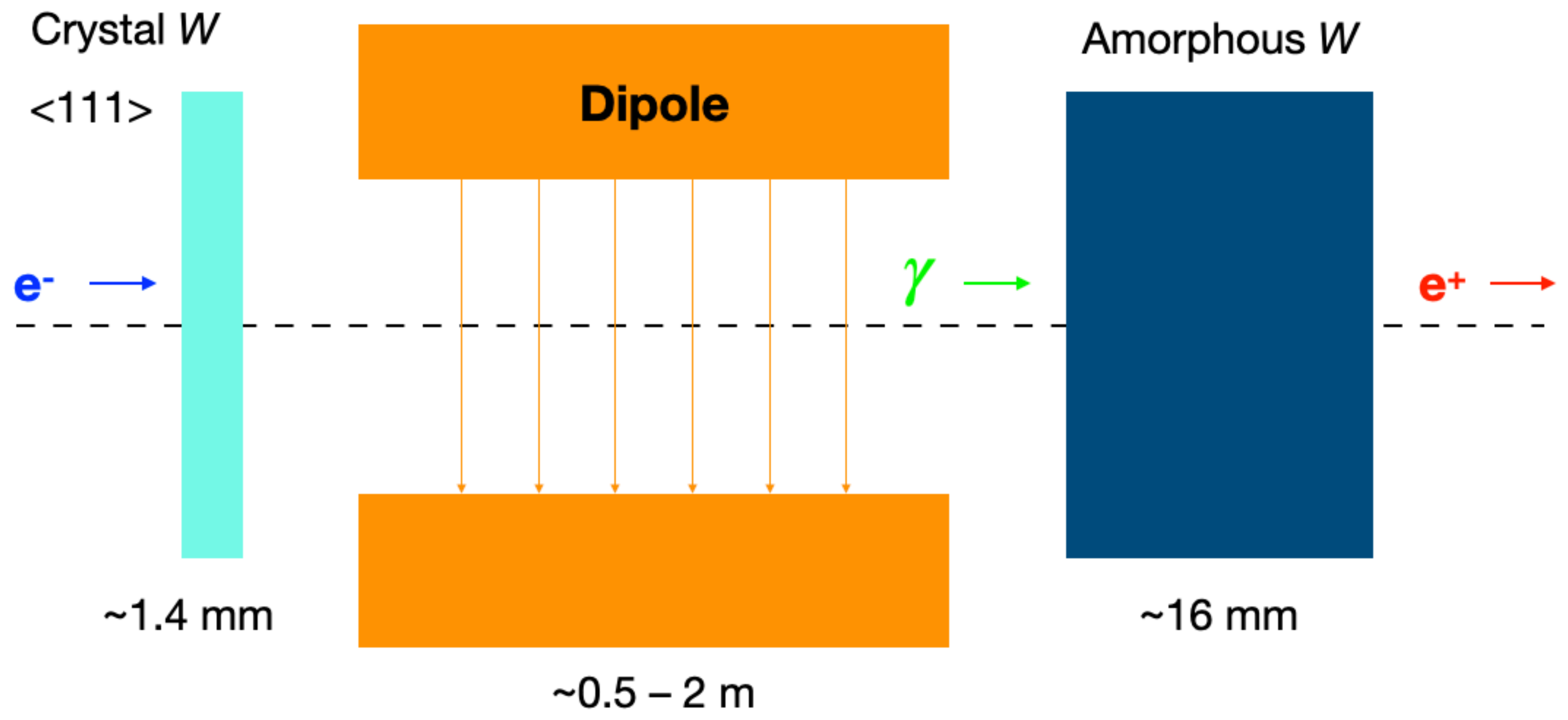


Fig. 1: Hybrid target scheme

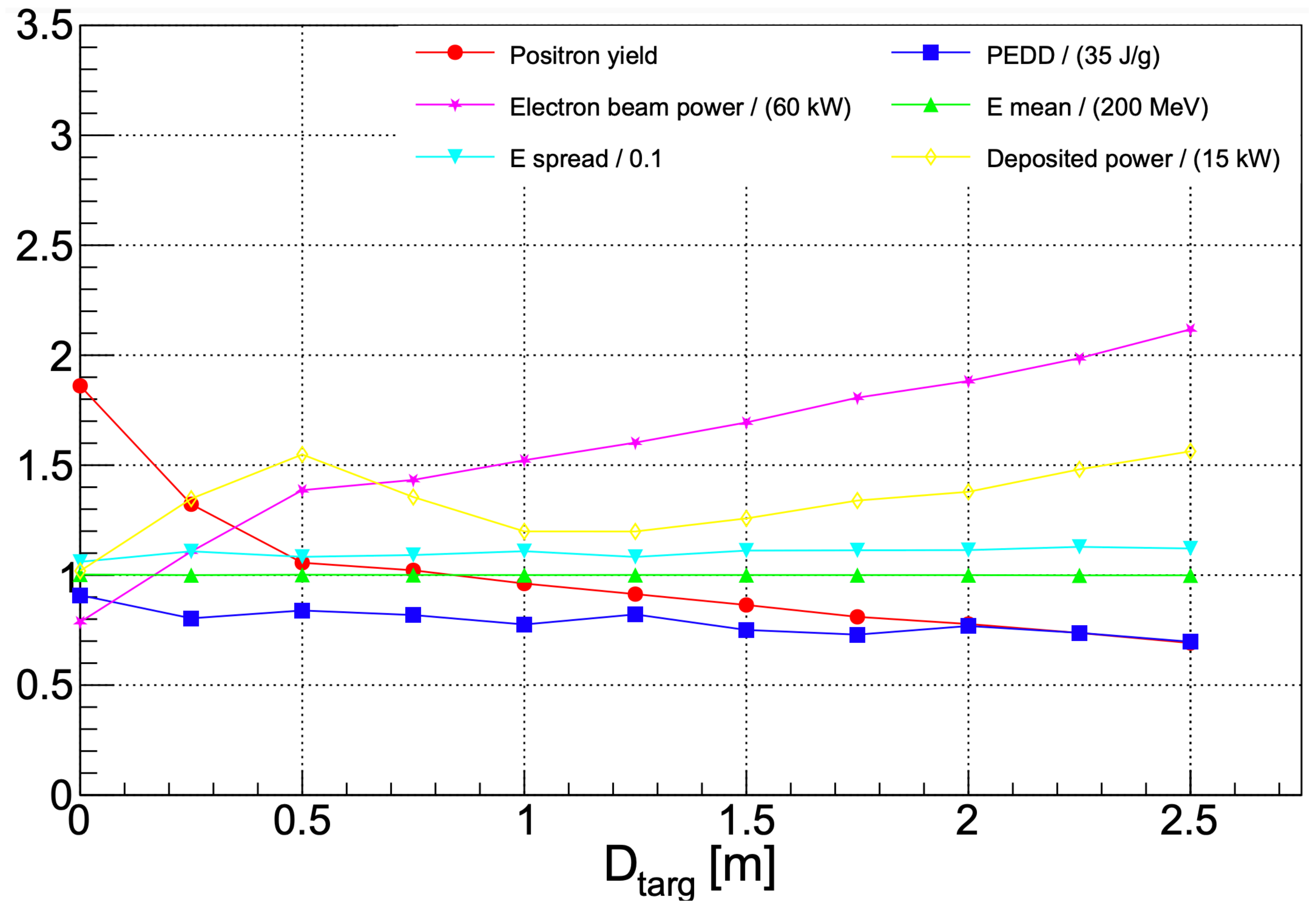


Fig. 2: scan of distance between hybrid targets

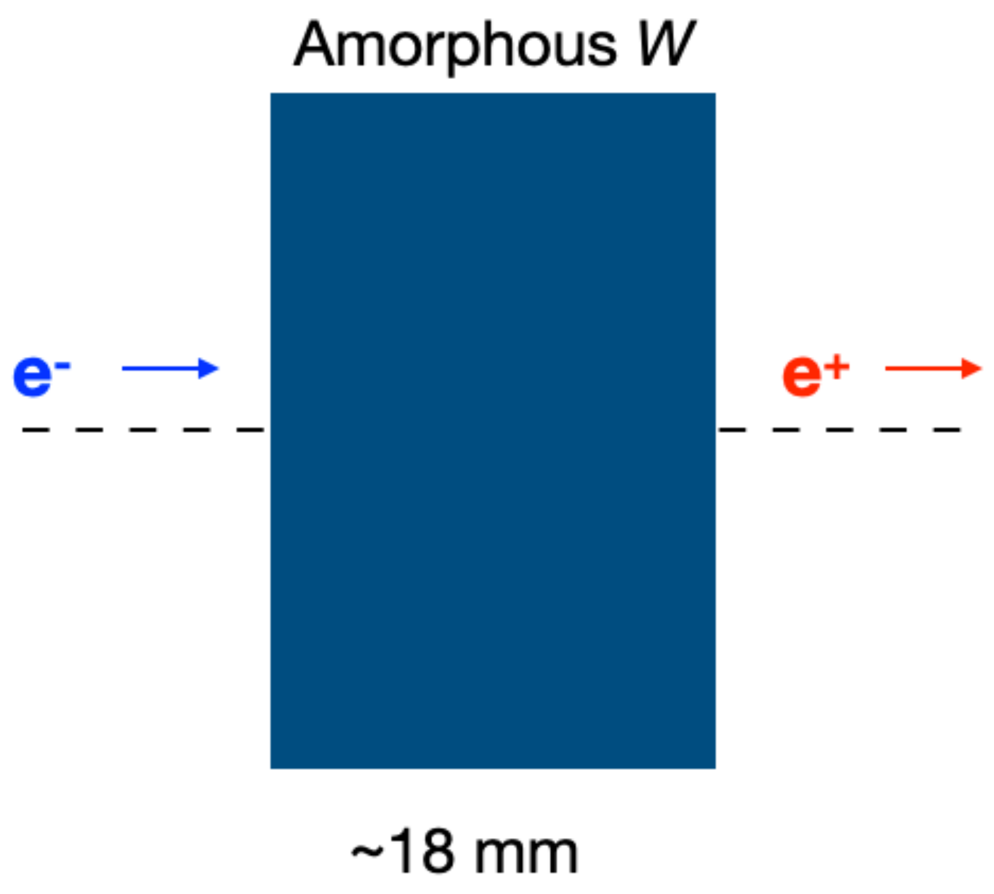


Fig. 3: Conventional target scheme

AMD

- **Analytic profile**
  - Analytic formula for on-axis field

    $B_z = B_0/[1 + \mu(z - 5\,\mathrm{mm})]$
  - Assuming conical (linear) apertue
- **Realistic SLAC-like FC design** (Fig. 1)
  - Linear aperture
    - Higher peak field
    - Higher e+ yield
  - Non-linear aperture
    - Lower peak field
    - Lower e^+ yield
    - Reduced power supply, voltages & forces

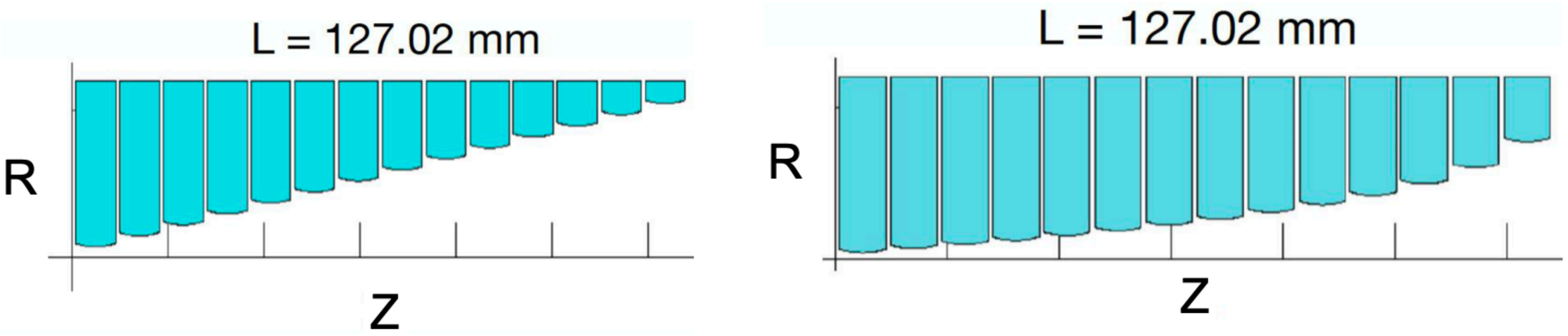
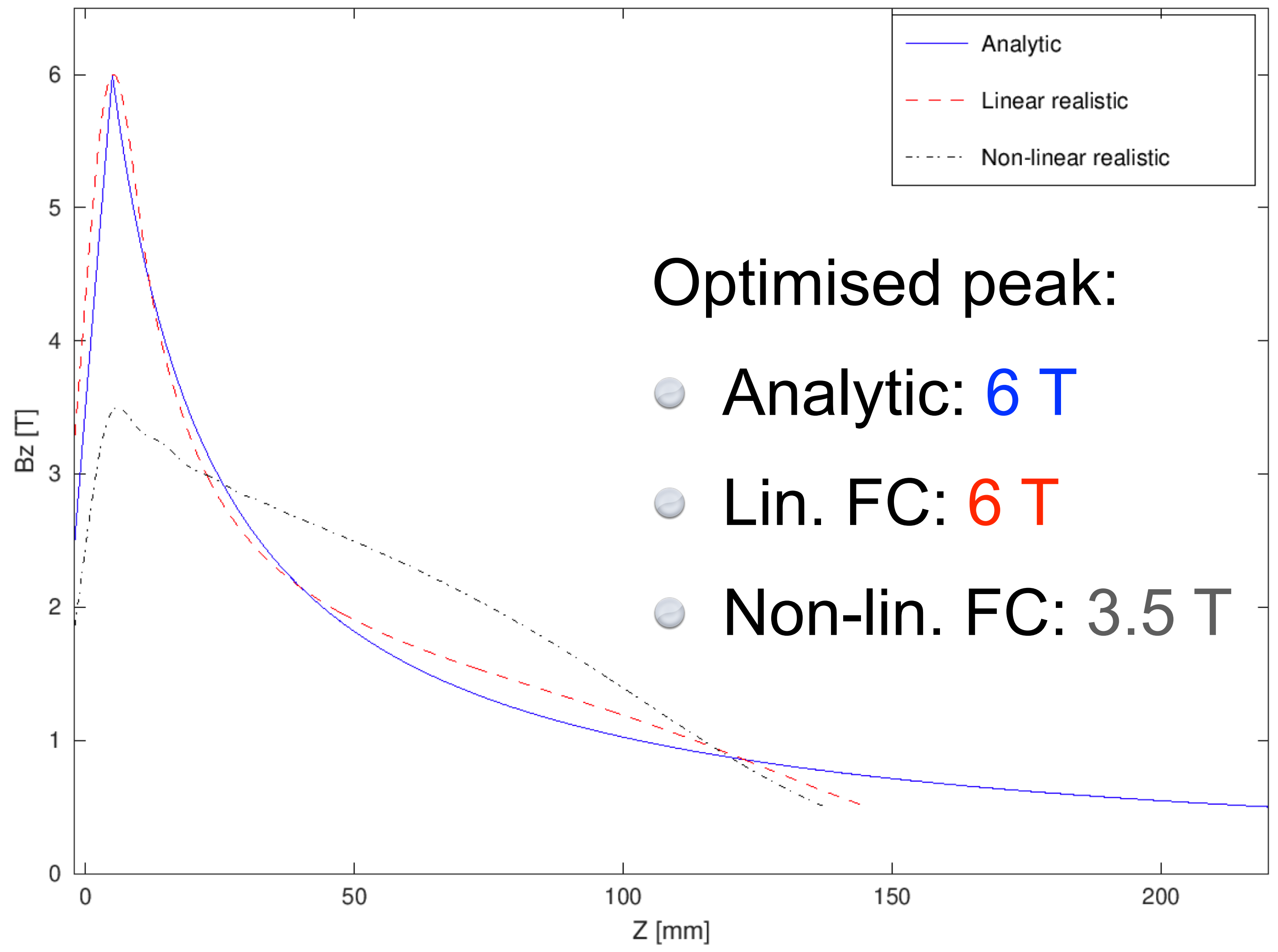
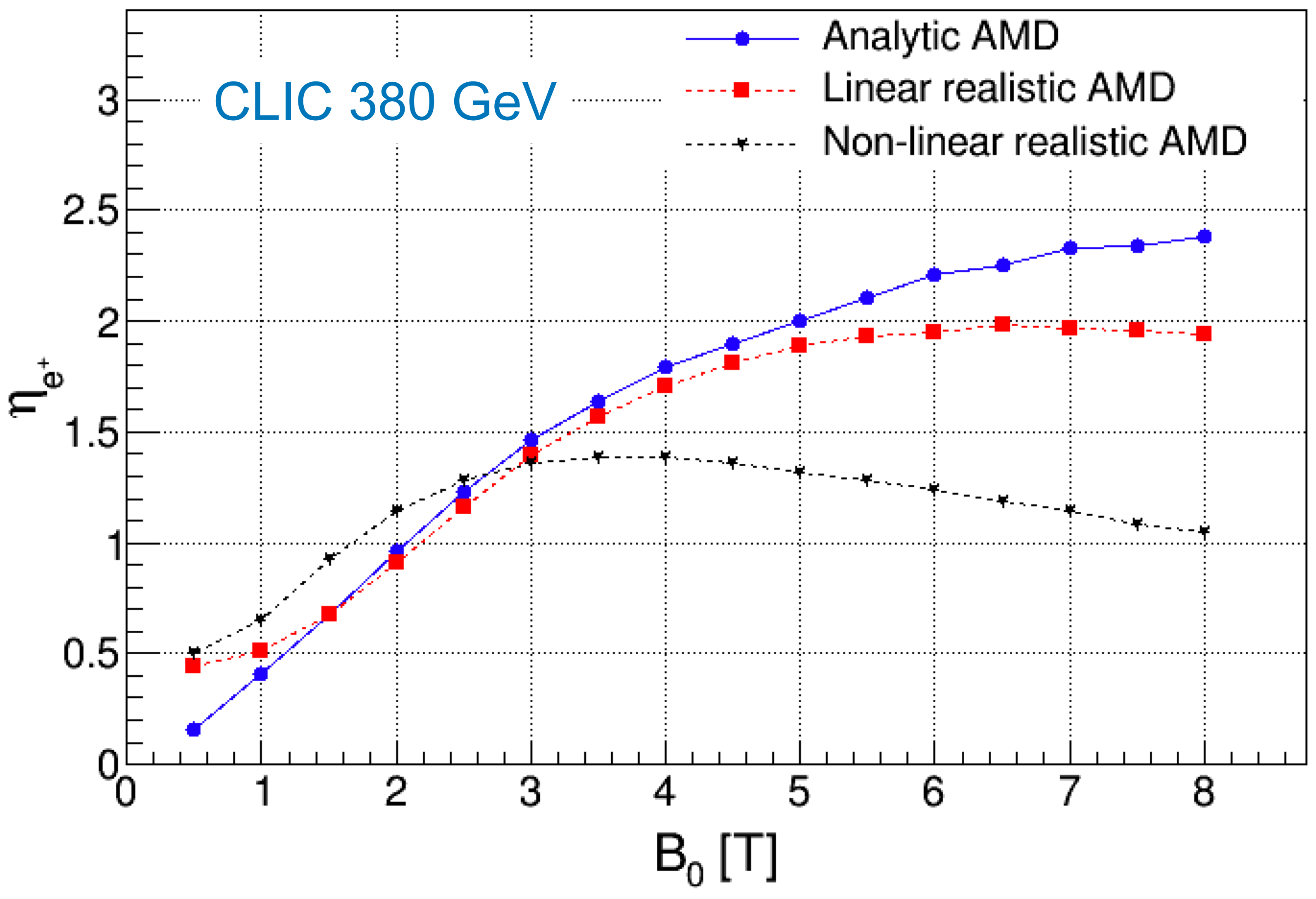


Fig. 1: FC schemes

- **On-axis field comparison**



- **Positron yield v.s. peak field**



Pre-injector linac

- L-band TW, 2π/3 mode, 2 GHz, aperture: 20 mm (R)
- No. of RF structures: 1 dec. + 10 acc.
- NC solenoid: 0.5 T

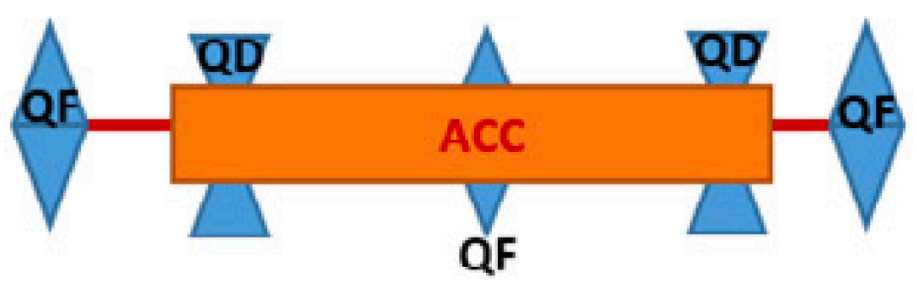
Injector linac

- **In optimisation**

$$\Delta E = (2.86\,\mathrm{GeV} - E_{\mathrm{ref}}) \cdot \cos[\omega \cdot (t - t_{\mathrm{ref}})]$$

Reference particle with energy around 200 MeV

- **In final simulation**
  - Existed design with 5 different FODO sections
  - 143 quadrupoles (16 for matching)
  - Good matching & no loss in yield



FODO sec. 1

FODO sec. 2

Beam parameters

- **e⁻ parameters**

Parameters	380 GeV	1.5 TeV and 3 TeV
Beam energy	5 GeV	5 GeV
Energy spread (RMS)	0.1%	0.1%
Normalised emittance (RMS)	80 mm·mrad	80 mm·mrad
Bunch length (RMS)	1 mm	1 mm
Number of bunches per pulse	352	312
Repetition rate	50 Hz	50 Hz

- **e⁺ parameters at the entrance of PDR**

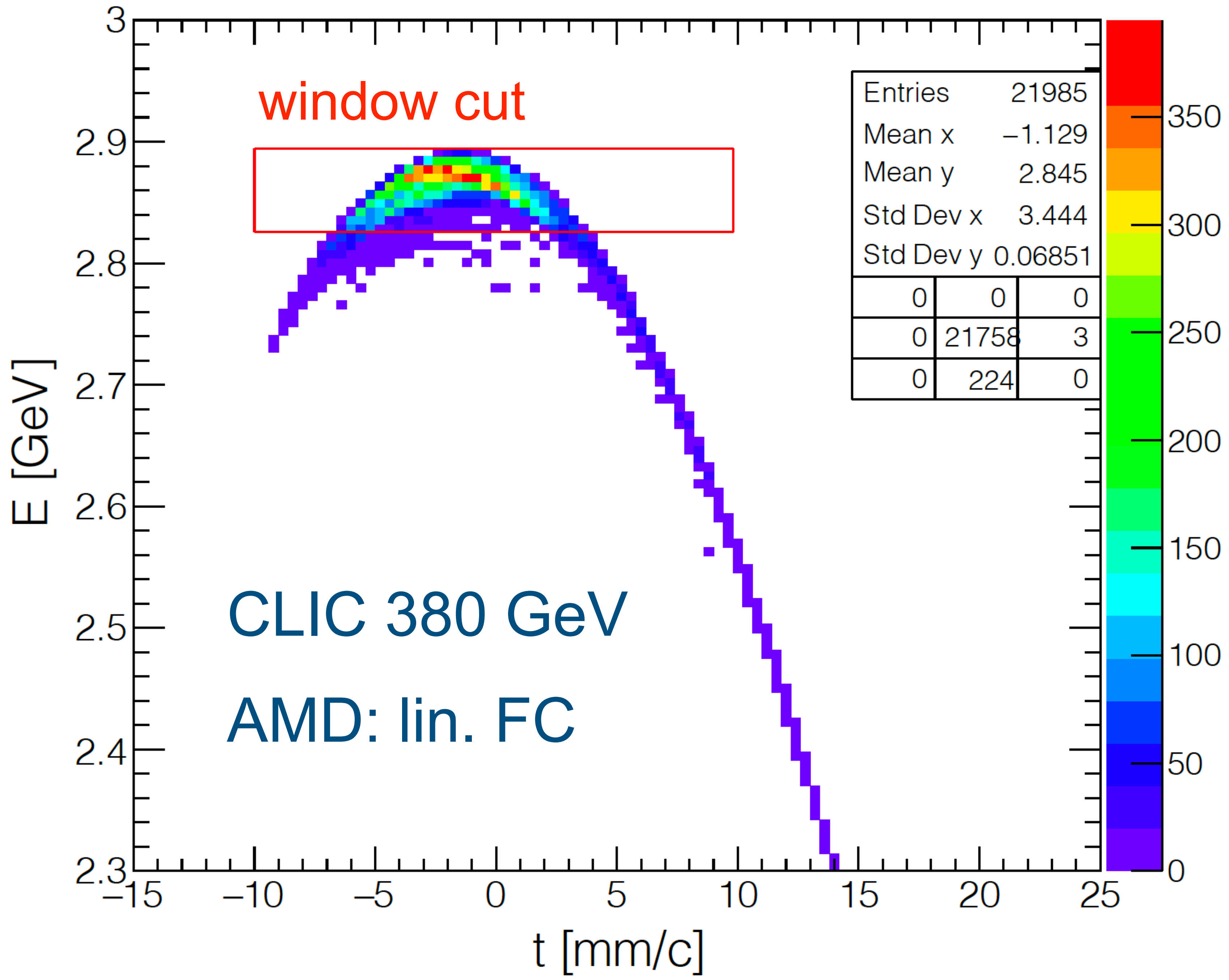
Parameter	380 GeV	1.5 TeV & 3 TeV
Energy acceptance (±)	1.2%	1.2%
Time window (total)	20 mm/c	20 mm/c
Bunch charge	5.2 x 10^9	3.7 x 10^9
Bunch charge safety margin	20%	20%

Final results

- **Optimised e^- spot size**

Spot sizes	380 GeV	1.5 TeV and 3 TeV
Analytic AMD	2.2 mm	1.5 mm
Linear realistic AMD	2.3 mm	1.5 mm
Non-linear realistic AMD	2.8 mm	1.8 mm

- **e^+ phase space at entrance of PDR**



- **Results at 380 GeV**

Results	Positron yield	PEDD	Deposited power	Beam power
Analytic AMD	2.15	32.2 J/g	11.2 kW	40.8 kW
Linear realistic AMD	1.91	33.0 J/g	12.6 kW	45.9 kW
Non-linear realistic AMD	1.31	33.5 J/g	16.3 kW	67.2 kW

- **Results at 1.5 TeV & 3 TeV**

Results	Positron yield	PEDD	Deposited power	Beam power
Analytic AMD	2.50	31.7 J/g	6.1 kW	22.2 kW
Linear realistic AMD	2.42	32.7 J/g	6.3 kW	22.9 kW
Non-linear realistic AMD	1.76	32.5 J/g	7.7 kW	31.4 kW

Summary

- Simulation of AMD and injector linac improved
- Beam, target and AMD reoptimised for lowest cost
- Final results given for different AMD profiles