Non Conventional Positron Target Scheme

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Outline

- Why Non-conventional Target Scheme
- Channeling Radiation
- Simulation Tools
- CLIC Positron Source
- FCC Hybrid Scheme
  - 4.46 GeV
  - 18.5 GeV
- Conclusion

Why Non-conventional target Scheme

Demonstrated positron source performance:

- SLC e+ source: 3.5e10 e+/bunch & 1 bunch/train & 120 Hz => 0.042e14 e+/s.
- KEKB e+ source: 6.25e9 e+/bunch & 2 bunches/train & 50 Hz => 0.006e14 e+/s.

Requirement for the next collider project:

- CLIC (380 GeV) e+ source: ~ 5.9e9 e+/bunch & 352 bunch/train & 50 Hz => ~0.92e14 e+/s
- ILC (250 GeV) e+ source: ~ 2e10 e+/bunch & 1312 bunch/train & 5 Hz => ~1.3e14 e+/s
- LHeC (ERL) e+ source: ~ 2e9 e+/bunch & 2e7 bunches/s (CW operation) => ~440e14 e+/s
- Muon Collider e+ source: ~ 1e9 e+/bunch & 1000 bunches/pulse & 10 Hz =>1.0e13 e+/s
- **FCC-ee e+ source: ~17e10 e+/bunch in the collider & 3 kHz => ~5e14 e+/s (only ~0.06e14 e+/s @ Injector)**

The conventional scheme presents some difficulties for the future collider:

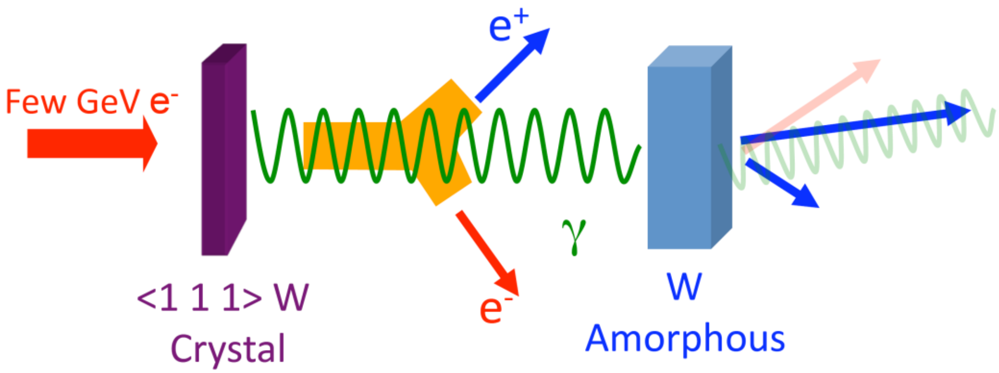
- Heating -> melting the target
- Peak Energy Density Deposition -> target breakdown

The energy on the target has to be limited.

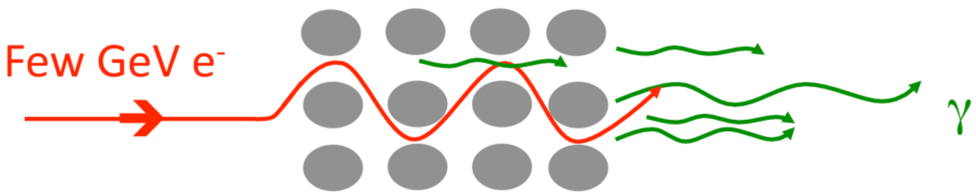
Why Non-conventional target Scheme

One solution is the hybrid target scheme:

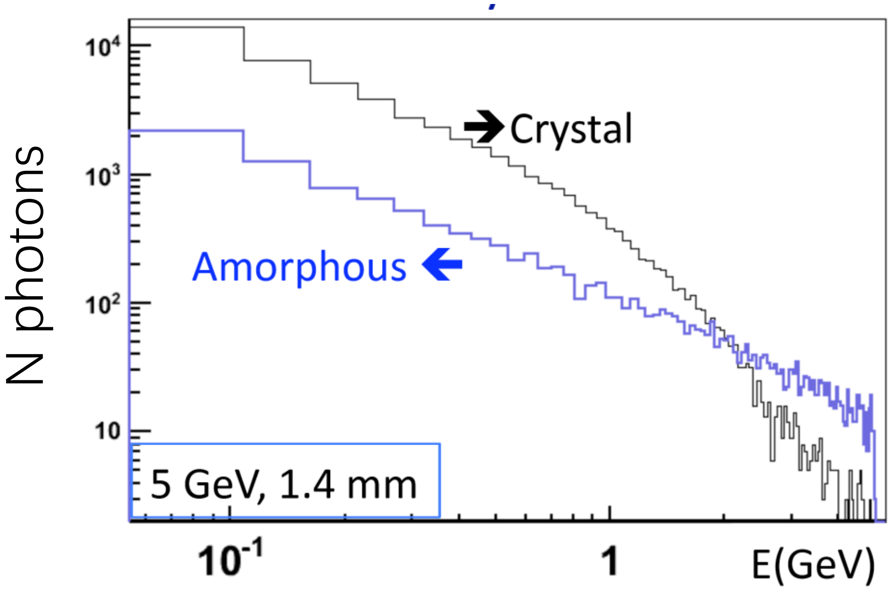
- Use a thin crystal radiator to provide a huge photons flux
- Spent the charged particle between radiator & converter
- Use amorphous target as converter



Why Crystal? The Channeling Radiation!

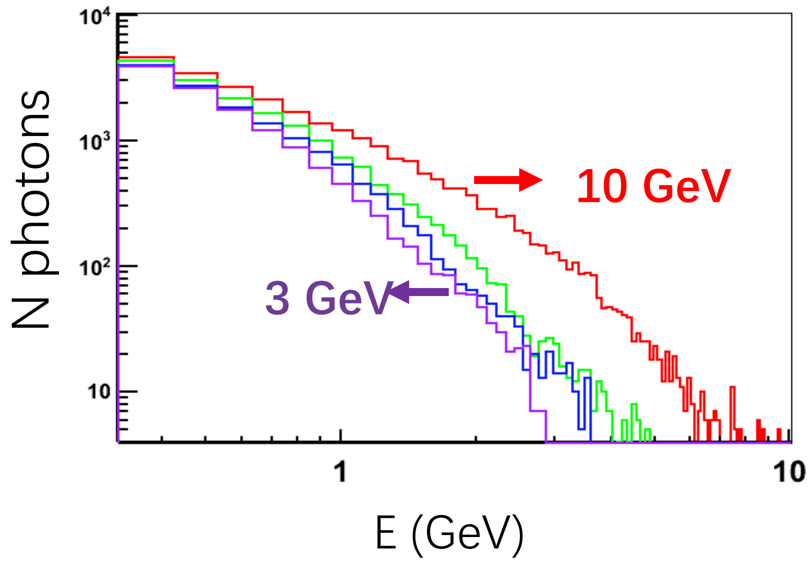


Enhancement of γ production w.r.t. to pure Bremsstrahlung process.



The Channeling Radiation in Crystal

- The higher the electron energy, the stronger the enhancement



- The photon yield and the radiated energy are increasing with the crystal thickness. But some saturation effect appears.
- Some crystals with high Z provide high potential values. Tungsten is used.

Several experiments had been conducted to study the hybrid e+ source (proof-of-principle experiment in Orsay, experiment @ SLAC, experiment WA 103 @ CERN and experiments @ KEK).

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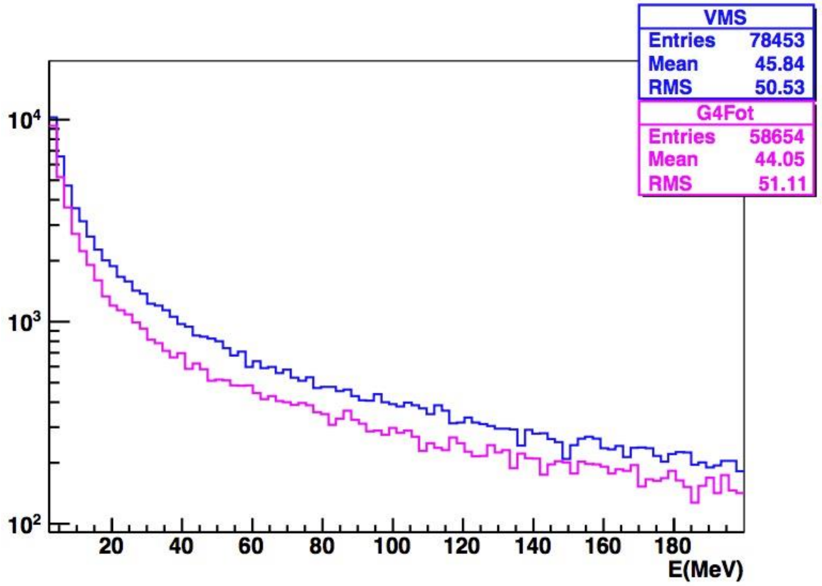
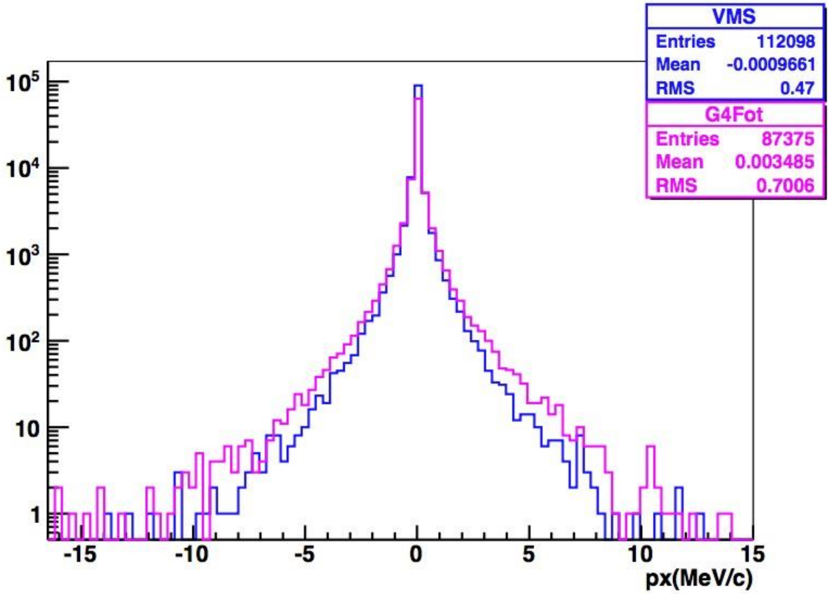
The simulation tools – Channeling Process

There are two programs to simulate the crystal channeling process

- **VMS** by V. M. Strakhovenko (Budker-INP, Russia)
  - Be used for the simulations in CLIC CDR
  - Photon distributions with only 4 dierent electron energies are provided
- **FOT** by X. Artru (French National Centre for Scientific Research)
  - The primary electron energy and crystal thickness can be scanned



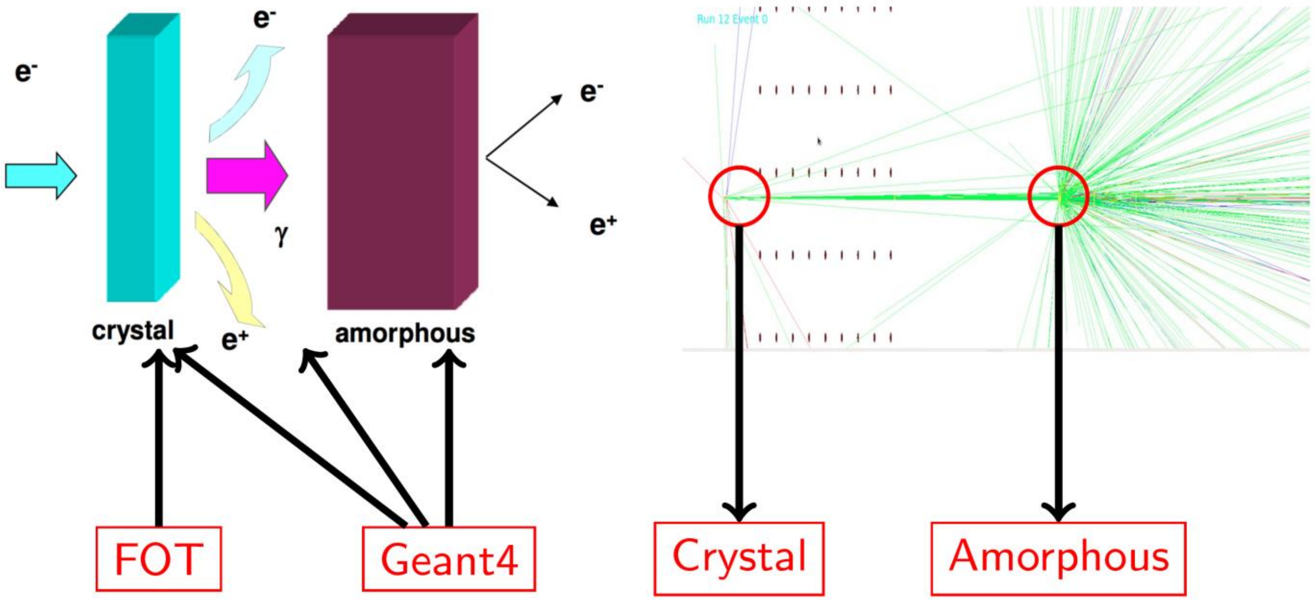
Energy distribution for photons



Px distributions for photons

The simulation tools

- FOT is used to generate photons in crystal tungsten (coherent & incoherent bremsstrahlung, channeling)
- These photons are set as primary particles in Geant4.
- Standard EM process in Geant4 is simulated in crystal & amorphous tungsten targets.



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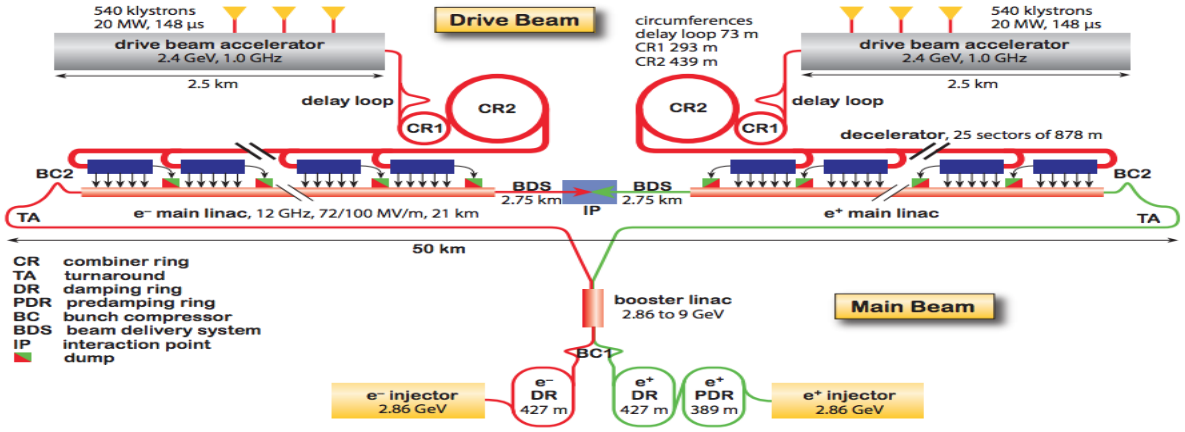
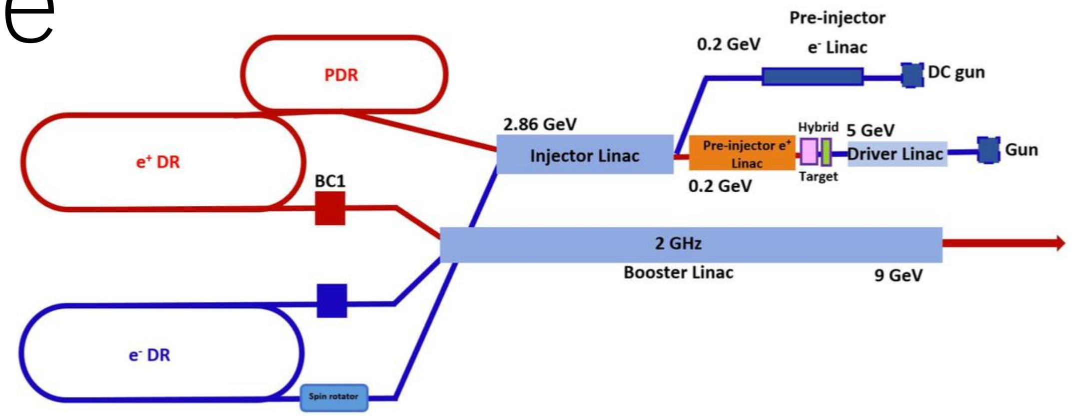
The CLIC Positron source





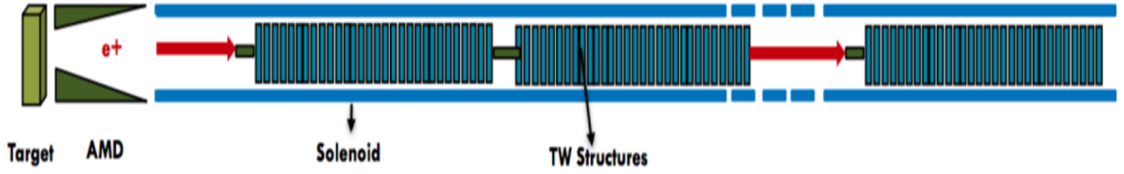


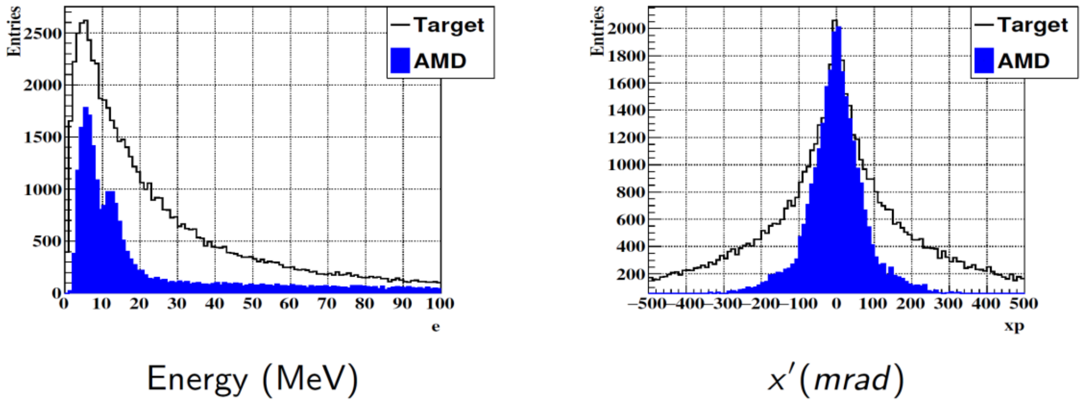
Table: Beam parameters at the entrance of pre-damping ring

Parameters	Value	
	3 TeV	380 GeV
E [GeV]	2.86	2.86
N [10^9]	6.6	9.3
n_b	312	352
$\Delta t_b[ns]$	0.5	0.5
$\epsilon_{x,y}[\mu m]$	7000	-
σ_z [mm]	5.4	5.4
σ_E [%]	4.5	4.5
f_{rev} [Hz]	50	50

1.6e14 positrons/s are needed @pre-damping ring.

- Incident electron beam energy: 5 GeV
- Hybrid target scheme is used as baseline
- AMD is used for capture: 6 T → 0.5 T
- L band traveling wave structures is used for capture & acceleration

The CLIC Positron Source



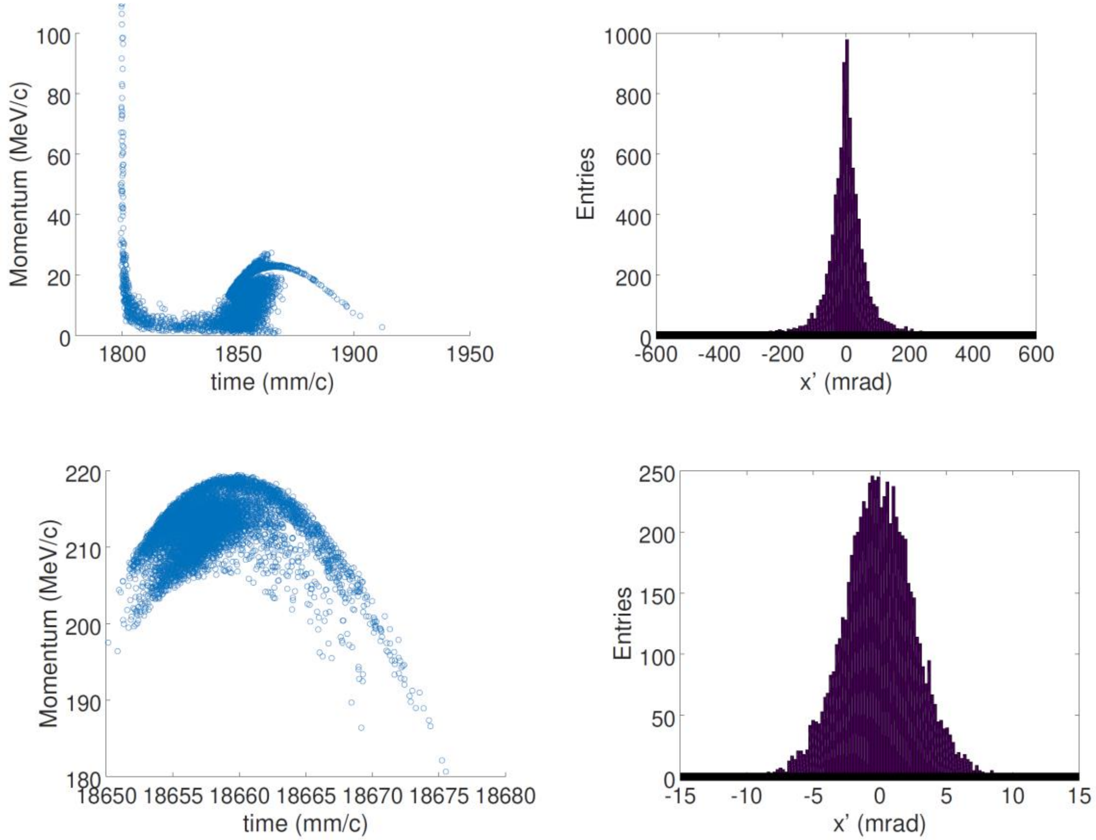
Energy & x’ distribution for target & AMD

Results using the hybrid target

Yield /PEDD [J/g] / Amor. Thick [mm]	5 GeV	3 GeV
2.5 mm spot size	1.30/17.7/16.6	0.76/17.1/12.3
1.25 mm spot size	1.94/29.3/14.9	1.03/26.7/11.5

Results using the conventional target

Yield /PEDD [J/g] / Amor. Thick [mm]	3 GeV
2.5 mm spot size	1.16/28.6/18
1.25 mm spot size	1.67/63/16



Longitudinal phase space & x’ distribution after the 1st and last traveling wave structure

The blue font: good for both stages; The red font: good for only the 3 TeV stage.

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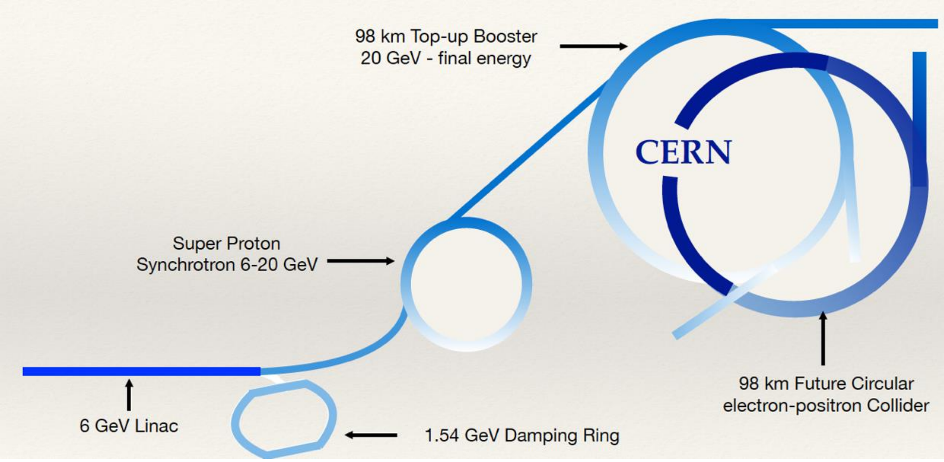
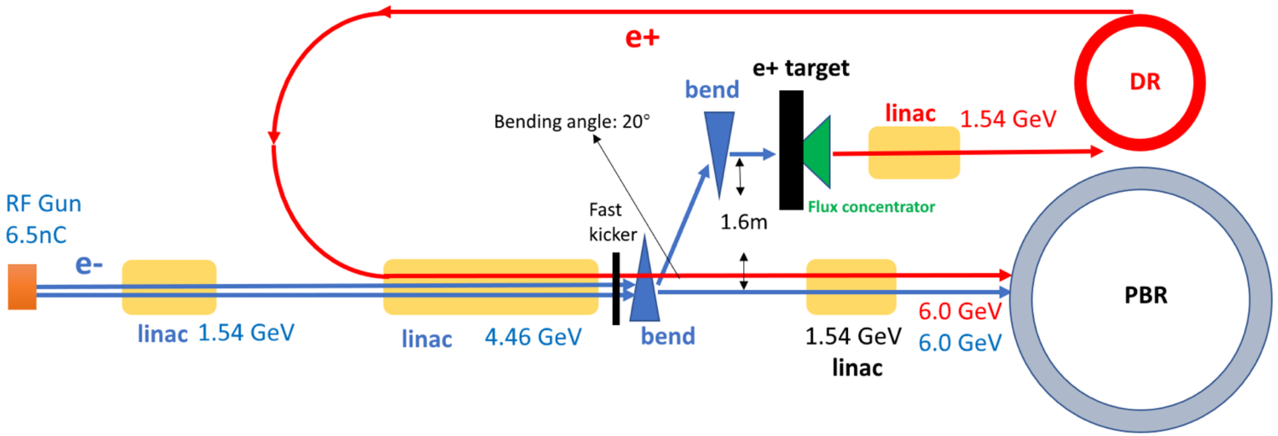
FCC-ee positron source

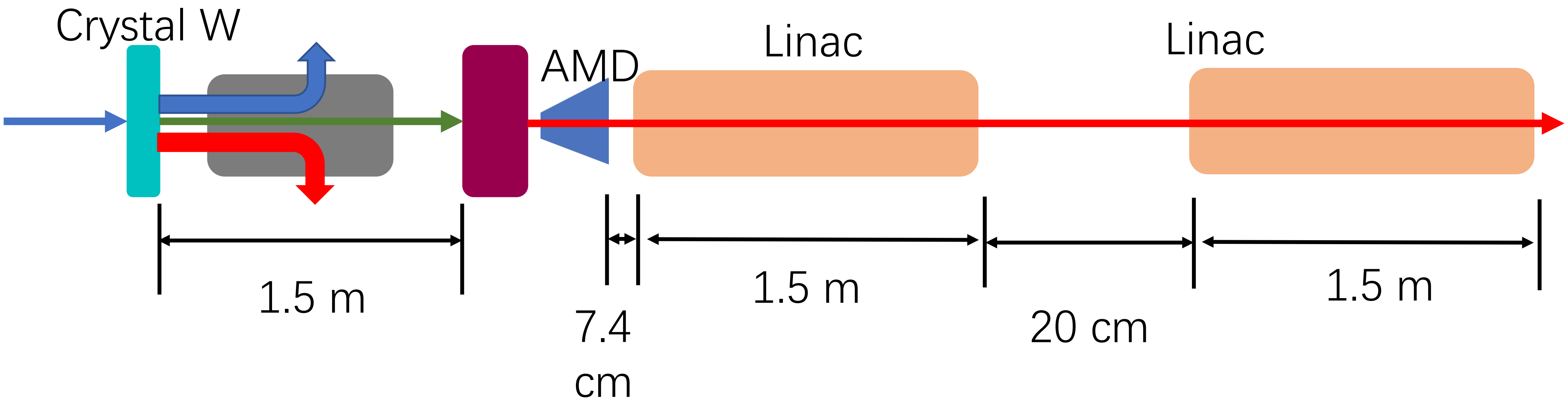




Requirements:

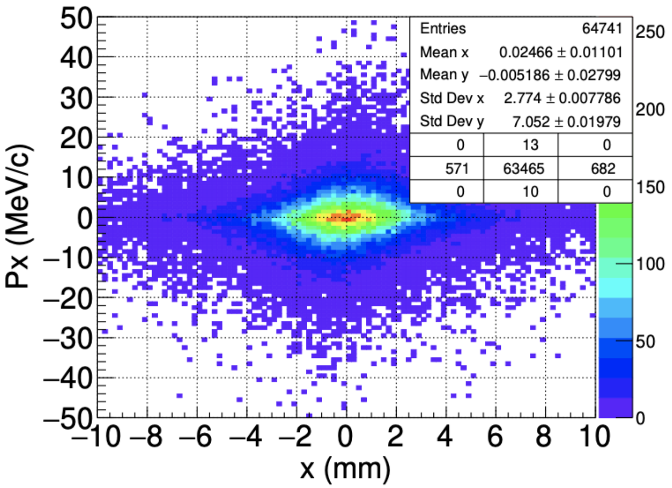
- Drive beam: 6.7 nC (4.2×10^{10}e^{+}) -- (up to 10 nC)
- 2 bunches spaced by 60 ns
- f_rep = 200 Hz
- Required positrons accetped by DR: 2.1×10^{10}

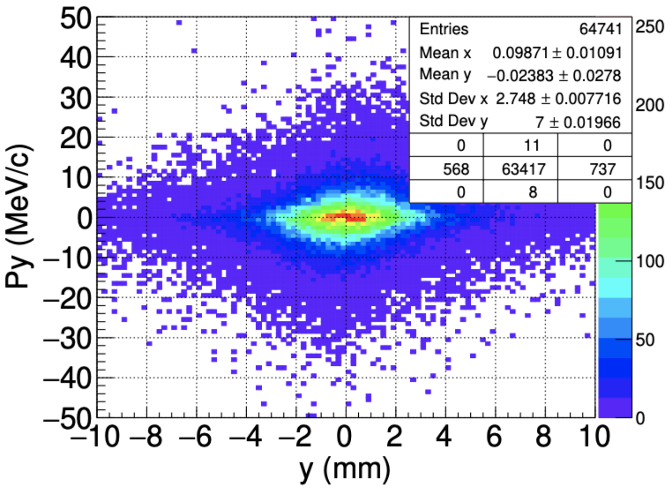
FCC positron source – CLIC like Hybrid Scheme

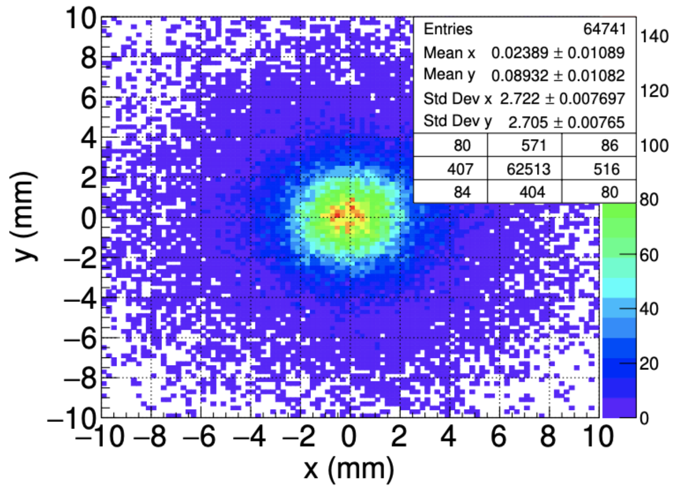


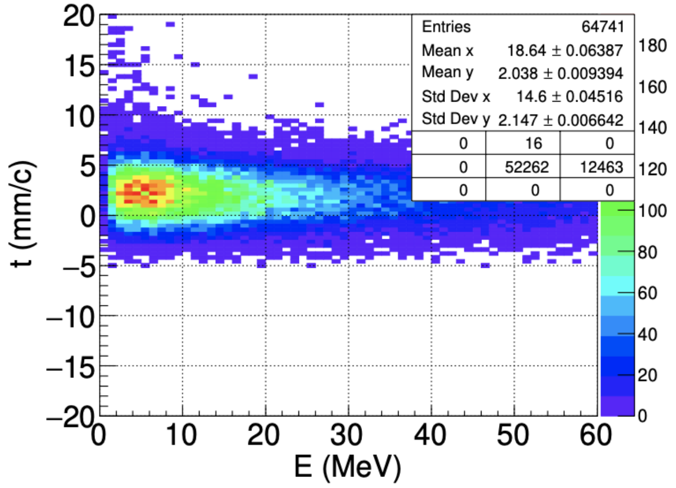
Parameters	Value	Parameters	Value
Energy (GeV)	4.46	Beam size (mm)	0.5
Crystal Thick (mm)	1.4	Bunch length (mm)	2
Distance (m)	1.5	$\Delta Pt/P$	10^{-5}
Amorphous Thick (mm)	12	$\Delta E/E$	10^{-3}

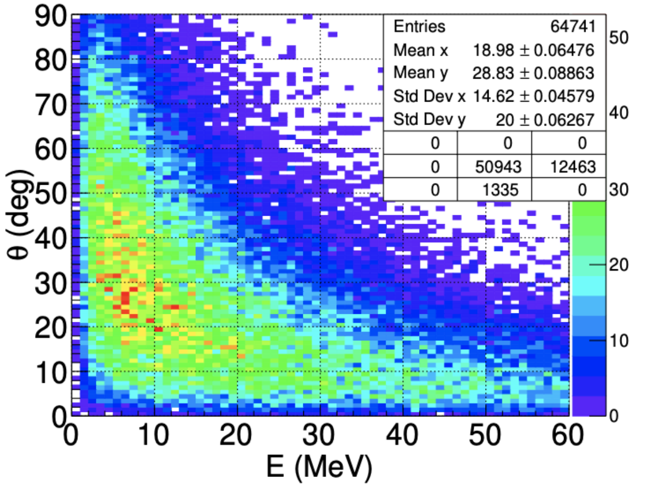
Phase Space after target











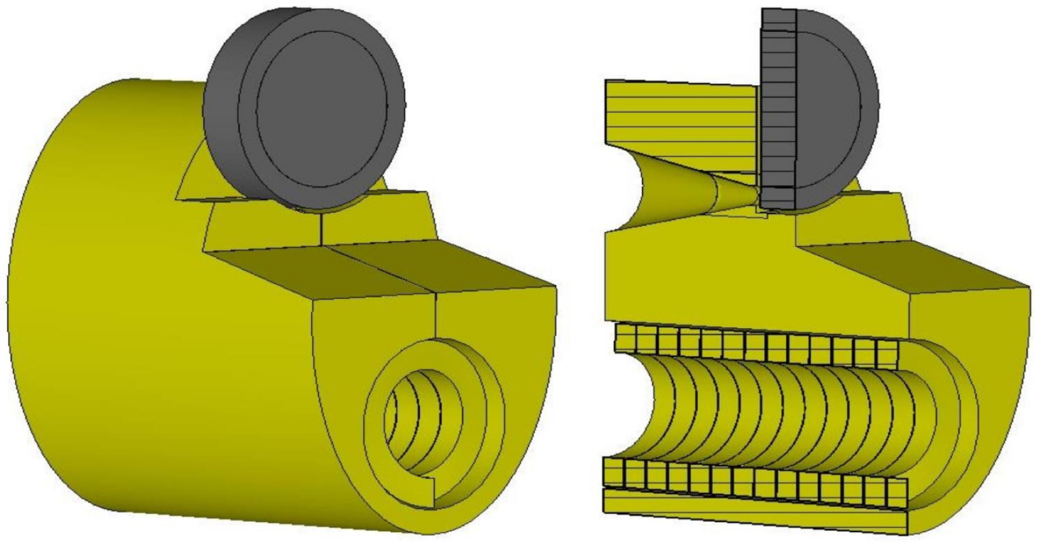
- The positron yield is 6.5 e^+/e^-
- The PEDD is 2.1 J/g
- The deposited power is 1.5 kW

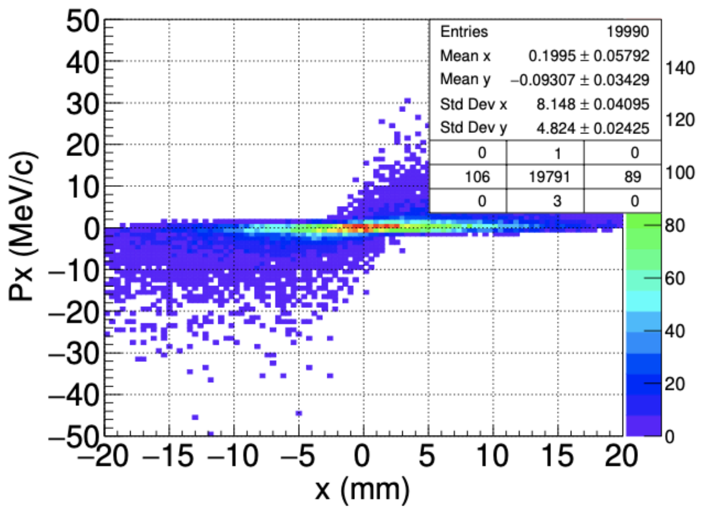
- P.S. Conventional scheme:
  - Yield: 10.5 e+/e-
  - PEDD 24J/g
  - Energy deposition 2.7 kW

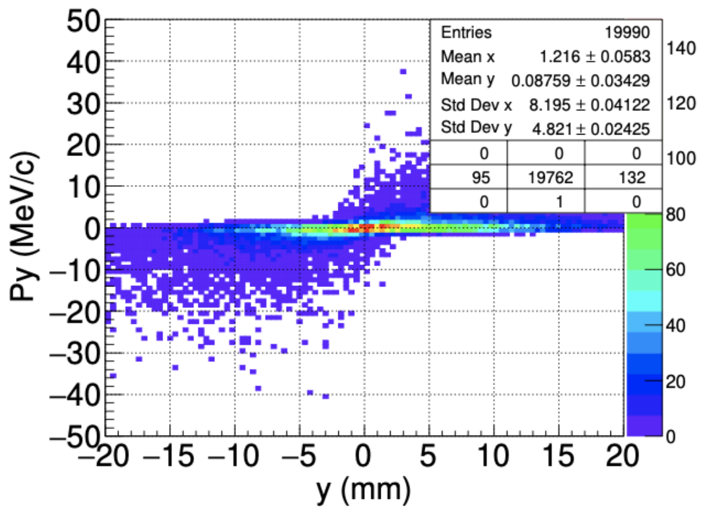
Designed by P. Martyshkin from BINP

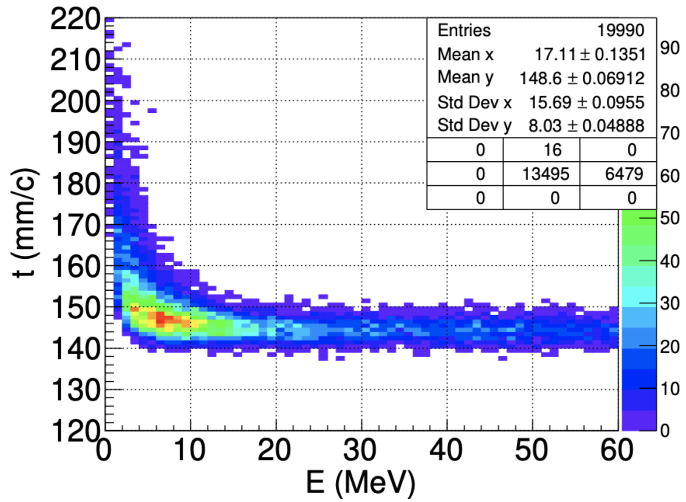
The Flux Concentrator – FCC design

- Peak field: 5 T
- DC solenoid: 0.5 T (uniform profile)
- Field on target: 3.9 T (surface of FC)
- 3D field map is provided
- **Positron yield: 2.0 e^+/e^-**









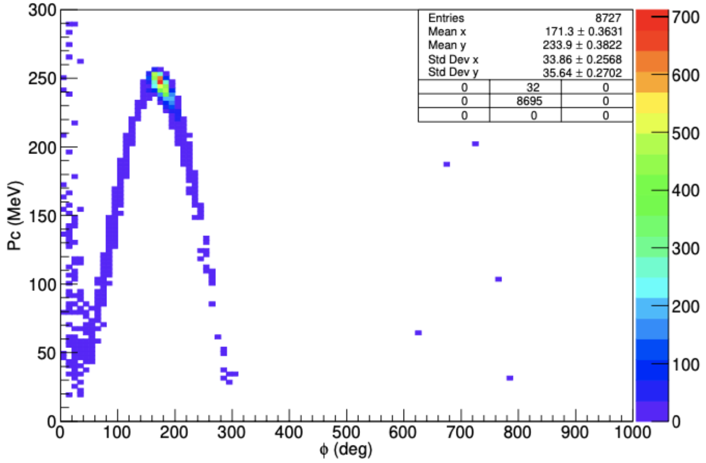
The traveling wave structures

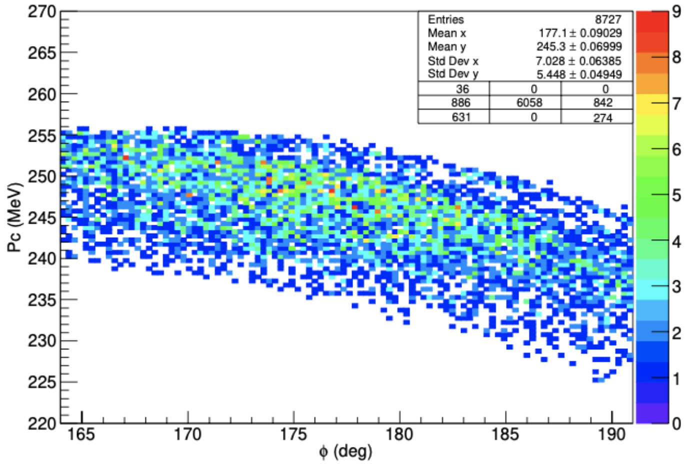
- Frequency: 2 GHz
- Number of cells: 30
- Length: 1.5 m
- Gradient: 16 MV/m
- Deceleration phase for 1st structure

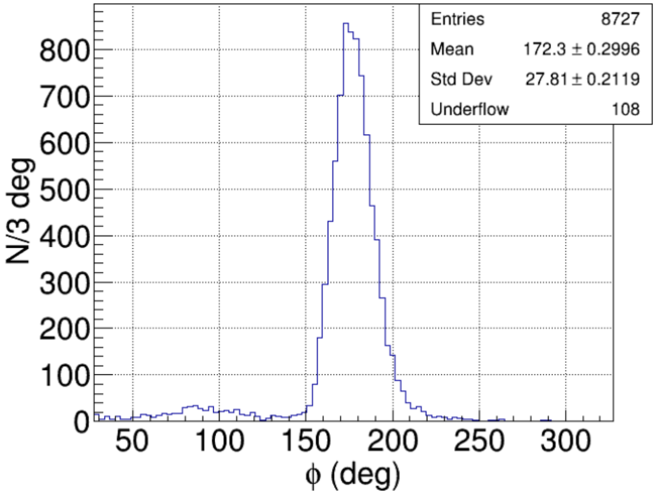
- Aperture: 40 → 28 mm (40 mm is used)
- Distance between two TWs: 20 cm
- Number of TWs: 11

Positron yield: 0.61 e^+/e^- (0.87 total)

<u>Cut applied:</u> ±4% energy acceptance and ± 13.5 deg RF (with S-band ~7.5 mm total)







Higher Field Flux Concentrator

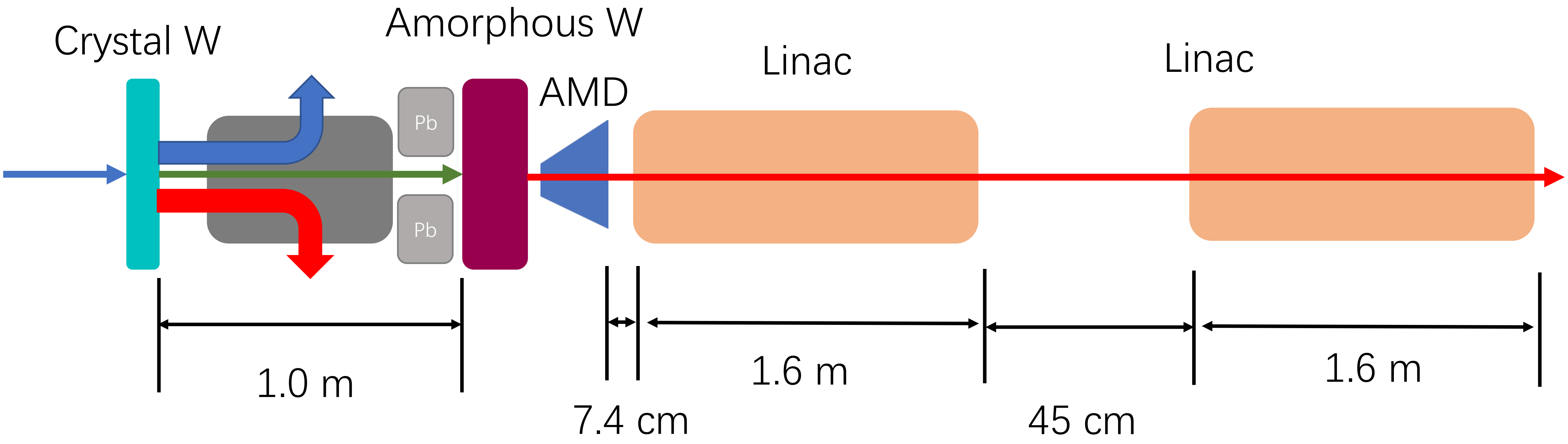
- A 7 Tesla peak field FC has also been designed for FCC.
- The DC field can reach 0.7 Tesla

Table: The summary for the CLIC-like configuration

Peak FC (T)	DC filed (T)	Yield@FC	Yield@TW	Yield@TW(cut)
5	0.5	2.0	0.87	0.61
5	0.7	2.1	1.06	0.65
7	0.7	2.4	1.30	0.74

The high peak field and DC field can improve the positron yield largely.

FCC positron source – Hybrid Scheme with Absorbers



- Several different FC and DC solenoid configurations are used

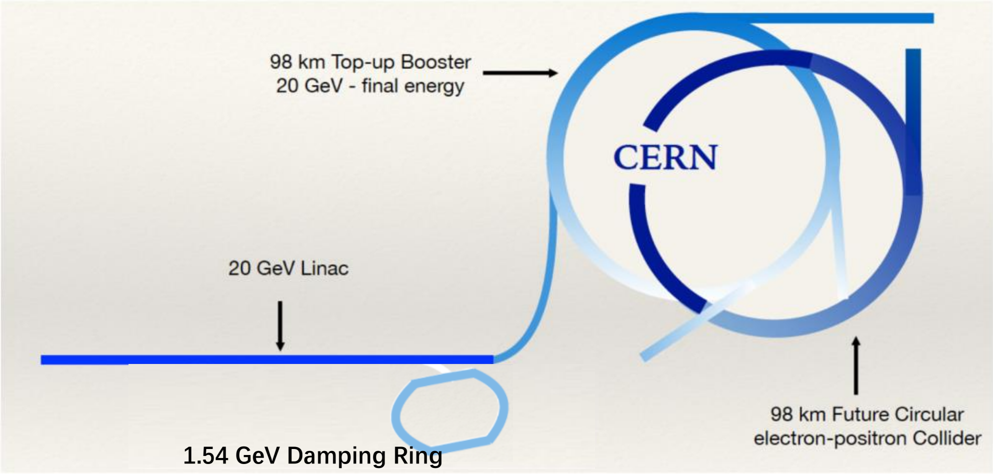
Simulation Results

FC aperture (mm)	Peak field(T)	DC field (T)	Dist (mm)	Yield@FC	Yield@TW	Yield@TW(cut)
8/44	5	0.5	2	2.35	0.96	0.58
8/44	5	0.7	2	2.45	1.22	0.61
8/44	**7**	**0.7**	**2**	**2.74**	**1.44**	**0.67**
16/64	5	0.5	5	2.99	1.26	0.53
16/64	5	0.7	5	3.23	1.75	0.61

- In current configuration, the larger aperture FC can not improve the positron capture efficiency.
    - The peak field is 5 Tesla for the larger aperture FC
    - The exit aperture of the larger aperture FC is too large

- The final effecitve positron yield can be improved largely with different traveling wave strucutres (longer Lband, normal Sband…)

FCCee alternative positron source



The simulation results using conventional scheme

Beam size (mm)	Yield@Target	PEDD (J/g)	Yield@FC	Yield@TWs
0.5	38.6	83.1	20.29	11.49
1.0	38.5	30.6	19.56	10.72
1.5	38.5	16.1	17.79	9.43
2.0	38.5	10.1	14.91	7.80
2.5	38.5	6.9	12.13	6.28
3.0	38.6	5.0	9.76	5.09

- 20 GeV Linac
- Energy of Incident electron beam: 18.5 GeV
- The conventional target scheme can give effective positron yield as high as 10e+/e-
- It is very promising using the hybrid target scheme for this option.

Conclusion

- The hybrid target scheme & the simulation toolkit for positron production are introduced
  - The main advantage is the low PEDD at the target
- The CLIC positron source based on the hybrid target is shown
  - The conventional target scheme can not provide enough positrons for CLIC
- The FCCee positron source is presented
  - The hybrid target scheme can largely reduce the PEDD for the FCC, with the cost of lower positron yield
  - It is very promising to use the hybrid scheme when the incident electron beam energy can be 18.5 GeV.

Thank you !!!