# Simulations of Positron Capture at Ce⁺BAF


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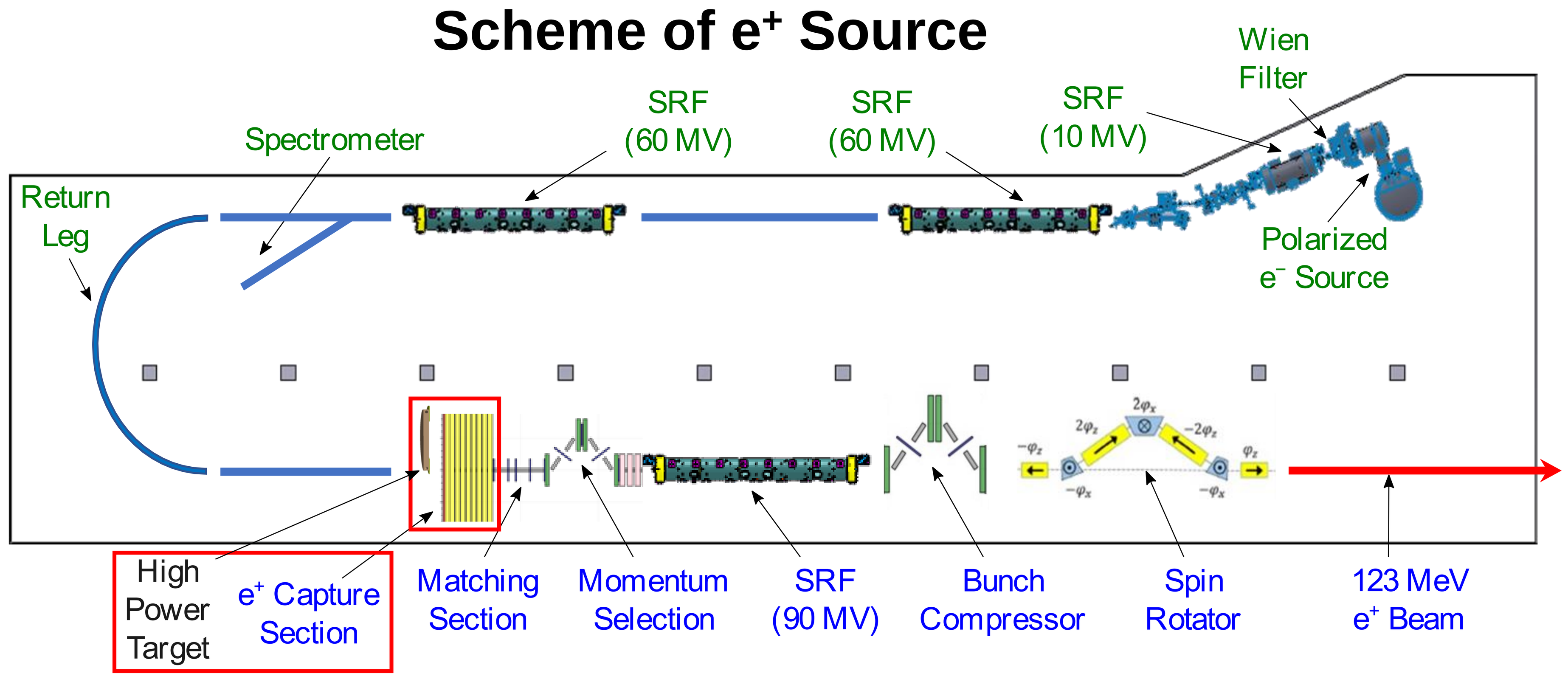
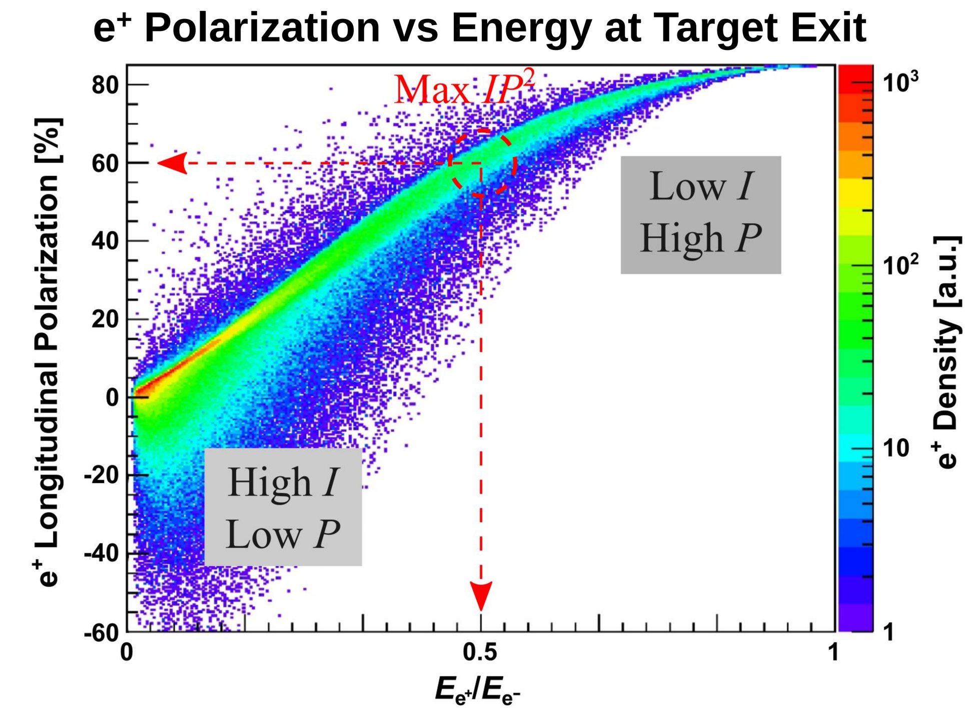
**Abstract**: We present a capture concept for the continuous wave (CW) polarized positron injector for the Continuous Electron Beam Accelerator Facility (CEBAF) at Jefferson Lab (Ce⁺BAF). This two-step concept is based on (1) the generation of bremsstrahlung radiation by a longitudinally polarized electron beam 1 mA, 120 MeV, 90% polarization), passing through a tungsten target, and (2) the production of e⁺e⁻-pairs by these bremsstrahlung photons in the same target. To provide highly-polarized positron beams (>60% polarization) or high-current positron beams (>1μA) with low polarization for nuclear physics experiments, the positron source requires a flexible capture system with an adjustable energy selection band. The results of beam dynamics simulations and calculations of the power deposited in the positron capture section are presented.


## Scheme of e⁺ Source




### e⁺ Polarization vs Energy at Target Exit

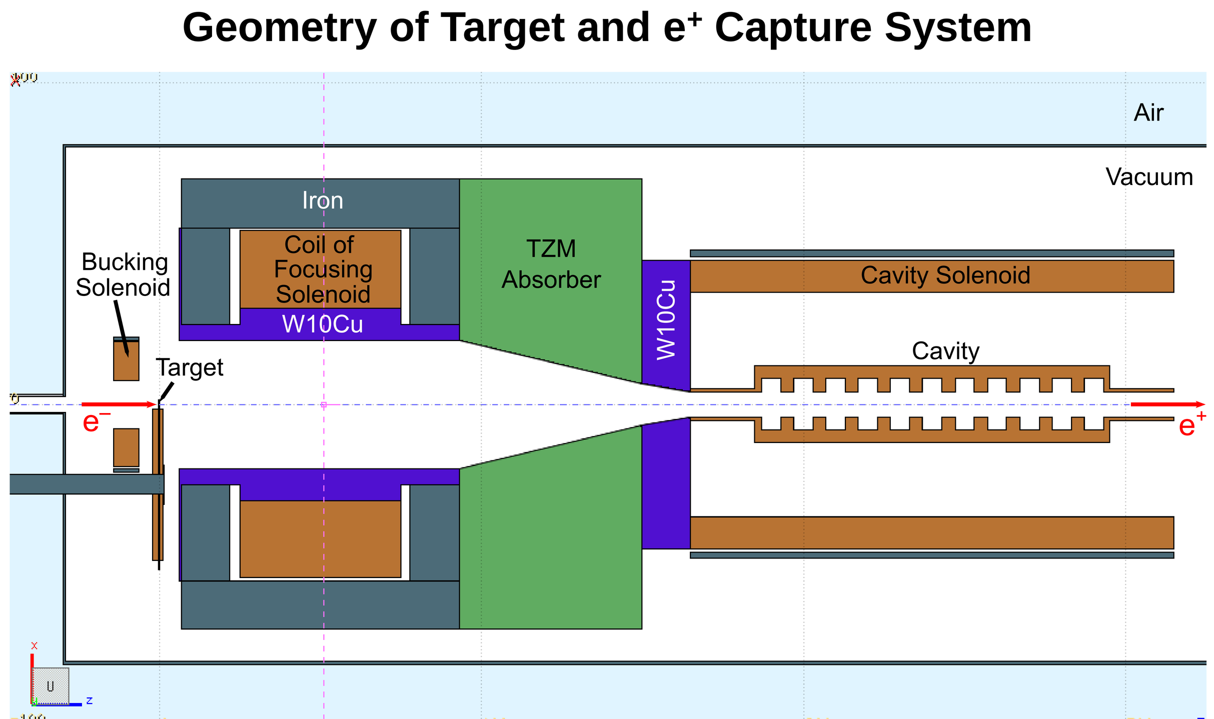



For max Figure-of-Merit ($FoM = IP^2$, where $I$ is e⁺ current and $P$ is e⁺ polarization):

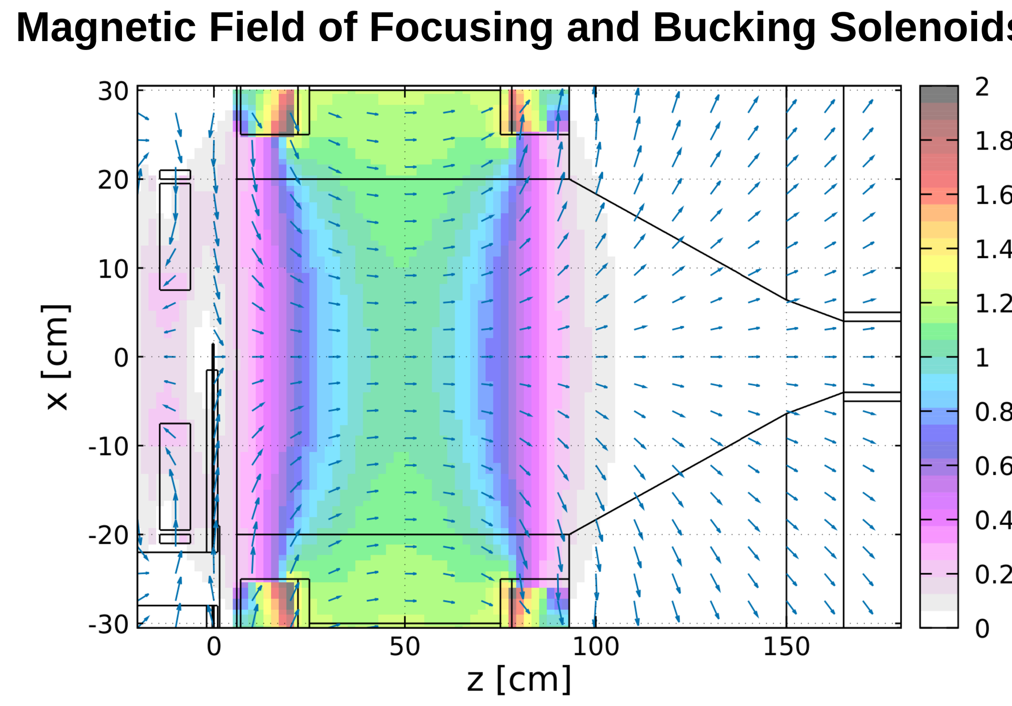
- Optimal e⁺ energy at target exit is about half of e⁻ drive beam energy [1].
- Positron polarization is ~60%.


[1] S. Habet *et al.*, "Characterization and optimization of polarized and unpolarized positron production", Tech. Rep. JLAB-ACC-23-3794, Feb. 2023. doi:10.48550/arXiv.2401.04484

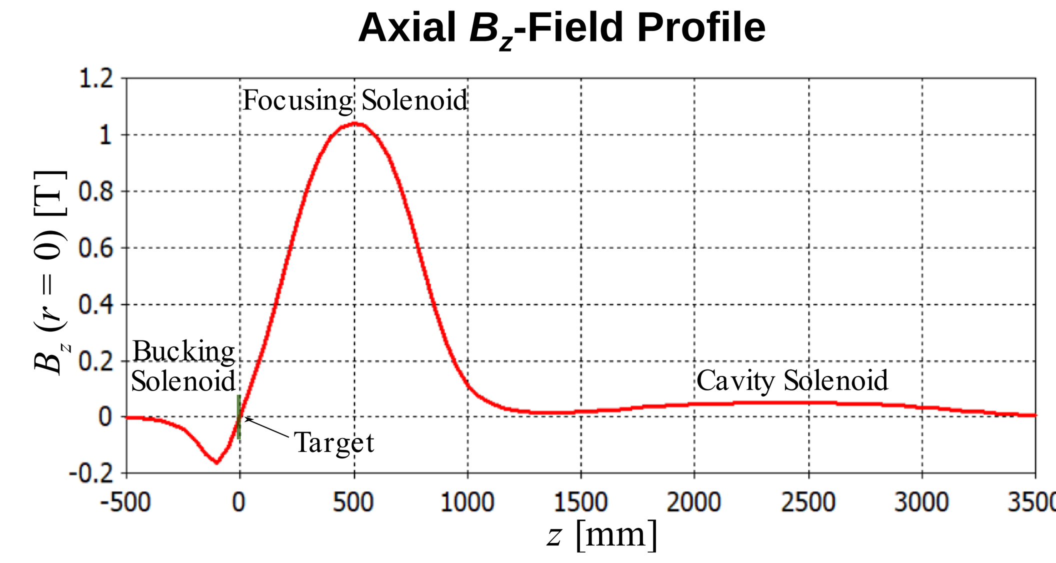

### Geometry of Target and e⁺ Capture System



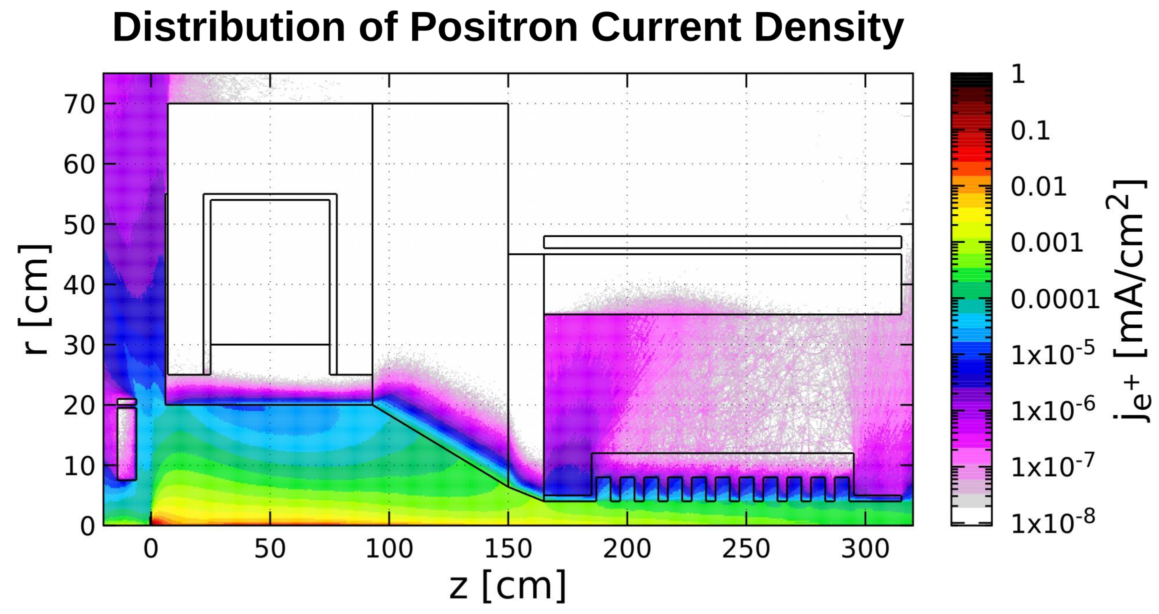

### Magnetic Field of Focusing and Bucking Solenoids



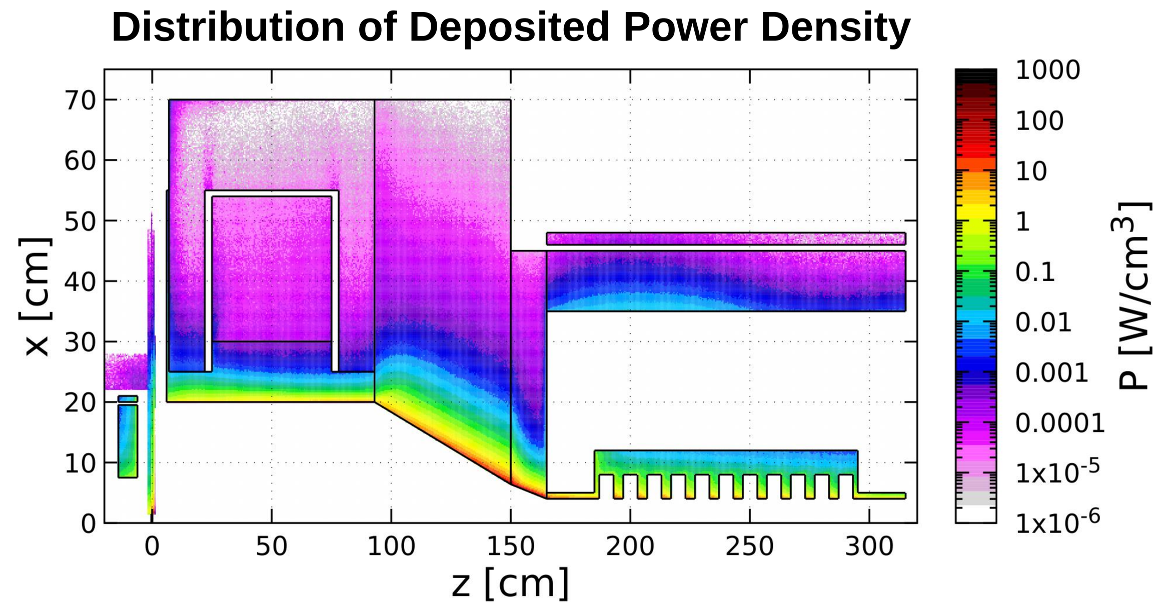

### Axial $B_z$-Field Profile




### Distribution of Positron Current Density



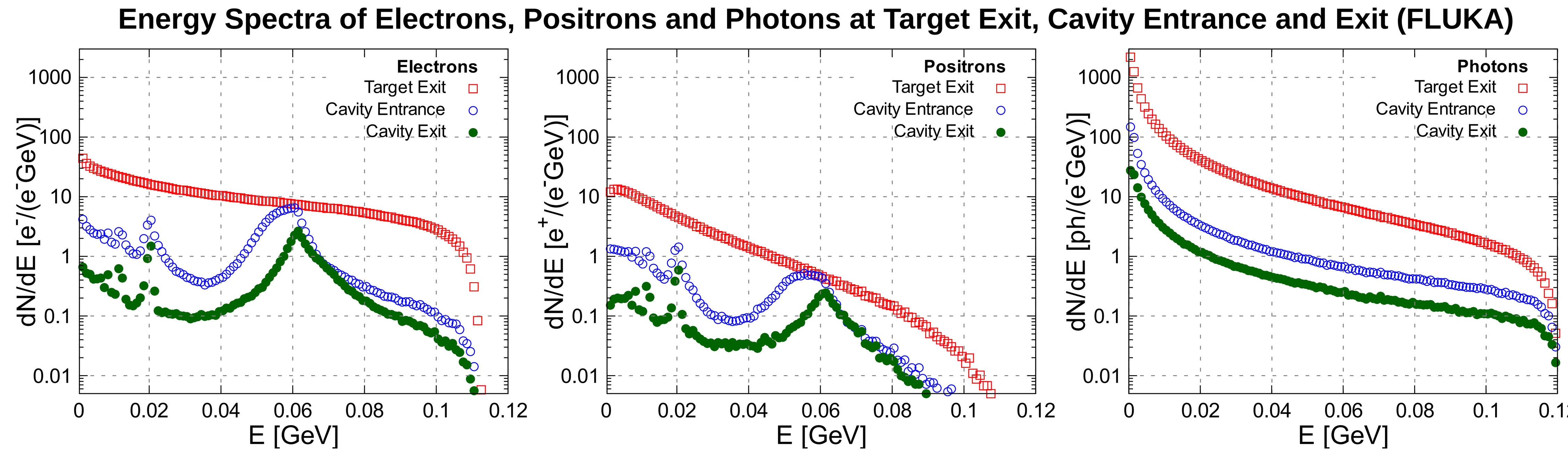

### Distribution of Deposited Power Density



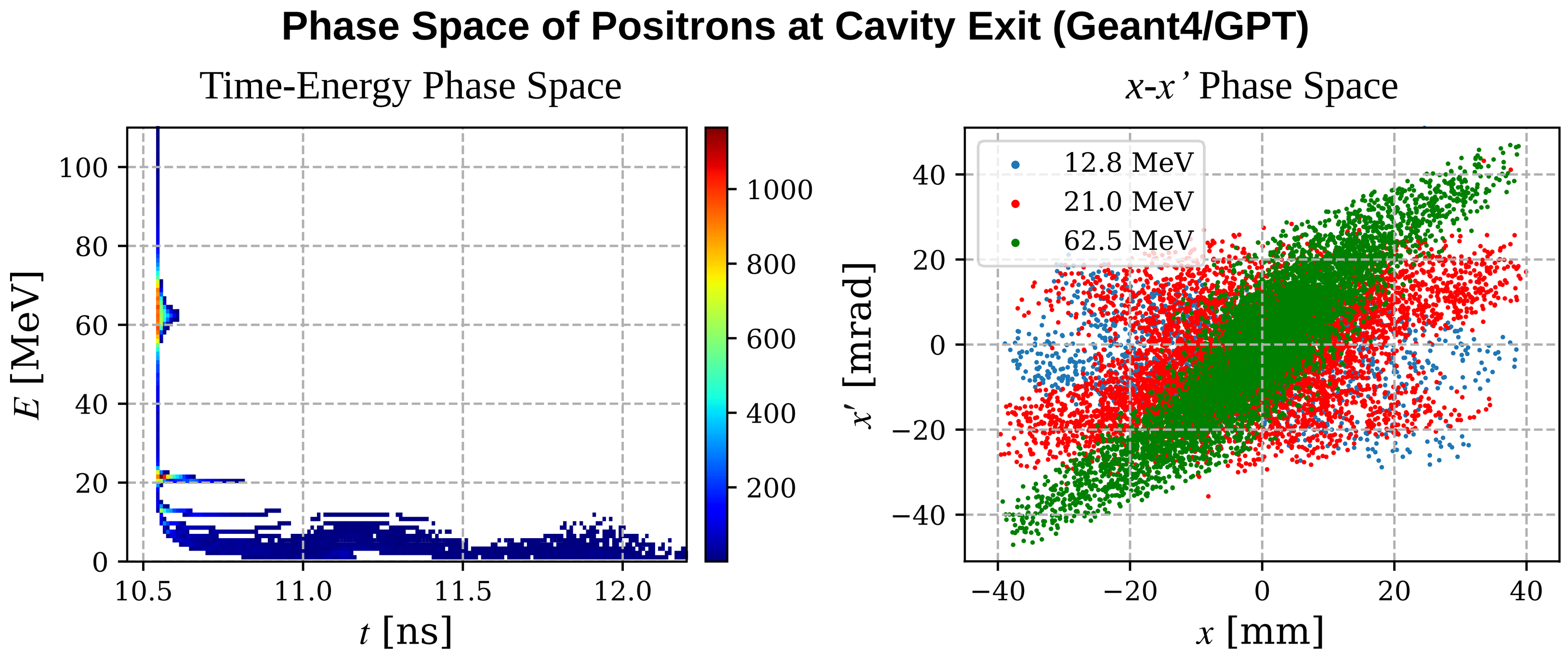

| Power of beams and absorbed power | Power [kW] |
|---|---|
| Primary e⁻ beam | 120.00 |
| *Absorbed beam power*: | |
| Bucking solenoid | 0.74 |
| Target | 18.32 |
| Coil of focusing solenoid | 0.02 |
| Iron of focusing solenoid | 0.07 |
| W10Cu shielding of focusing solenoid | 18.68 |
| TZM absorber | 54.96 |
| W10Cu absorber | 12.61 |
| Cavity | 8.50 |
| Cavity solenoid | 0.62 |
| Vacuum chamber and pipe | 0.60 |
| Total absorbed beam power | 115.12 |
| Power of $\gamma$, e⁻ and e⁺ at cavity exit | 4.76 |

| Yield/Energy/Power | $\gamma$ | e⁻ | e⁺ |
|---|---|---|---|
| Yield $[N_{\gamma,e^-,e^+}/N_{e^-_{primary}}]$ | 0.152 | 0.040 | 0.008 |
| Average energy [MeV] | 13.06 | 50.54 | 33.78 |
| Beam power [kW] | 1.99 | 2.03 | 0.27 |

### Energy Spectra of Electrons, Positrons and Photons at Target Exit, Cavity Entrance and Exit (FLUKA)




### Phase Space of Positrons at Cavity Exit (Geant4/GPT)




### Parameters of Primary e⁻ Beam and Positrons at Cavity Exit

| | | | |
|---|---|---|---|
| ***Primary electron beam*** | | | |
| Energy [MeV] | | 120 | |
| Current [mA] | | 1 | |
| Polarization [%] | | 90 | |
| ***Positrons at cavity exit*** | | | |
| Energy [MeV] | **62.5** | **21.0** | **12.8** |
| Energy spread [%] | | 2 | |
| Current [nA] | 609 | 678 | 156 |
| Normalized emittance [mm·rad] | 11.4 | 6.3 | 3.8 |
| Bunch length $\sigma_z$ [mm] | 4.5 | 11.3 | 8.4 |
| Polarization [%] | 71.9 | 26.5 | 15.9 |

## Summary and Outlook

The development of the Ce⁺BAF capture magnets and cavities and the simulation of the positron capture is a tightly coupled iterative process. First beam tracking simulations in realistic geometries and fields show promising results. The concept of the Ce⁺BAF injector [1], based on a rotated water-cooled tungsten target, a focusing solenoid with ≃1 T peak field on the beam axis, and a CW standing wave capture cavity, is capable of providing the required current of positrons with more than 60% polarization. The design of injector components, thermal and mechanical stress analysis, radiation damage and induced radioactivity calculations, and design of required shielding will be continued.


[1] J. Grames et al., "Positron beams at Ce+BAF", in Proc. 14th Int. Particle Accelerator Conf. (IPAC'23), Venice, Italy, May 2023, paper MOPL152, pp. 896–899. doi:10.18429/ JACoW-IPAC2023-MOPL152



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