实验物理中心2022年（9-12月）研究生考核报告

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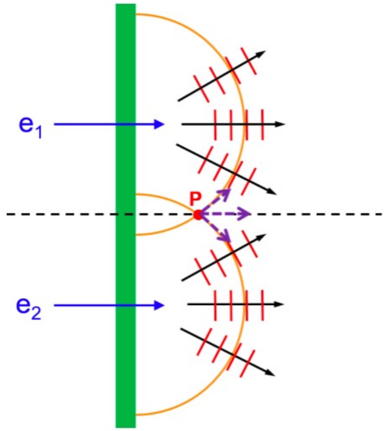
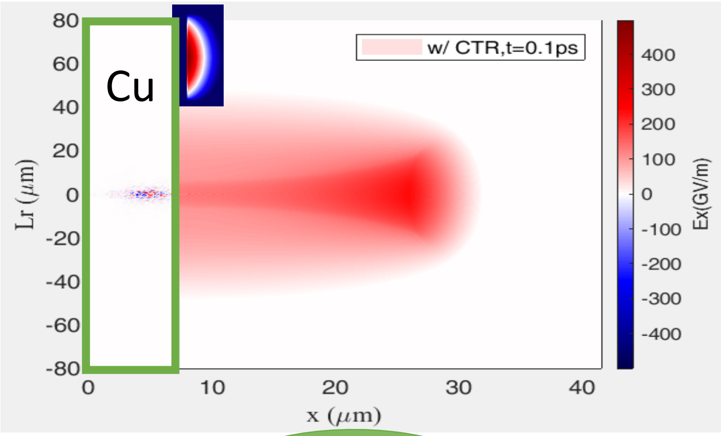
导师：阮曼奇/黄永盛

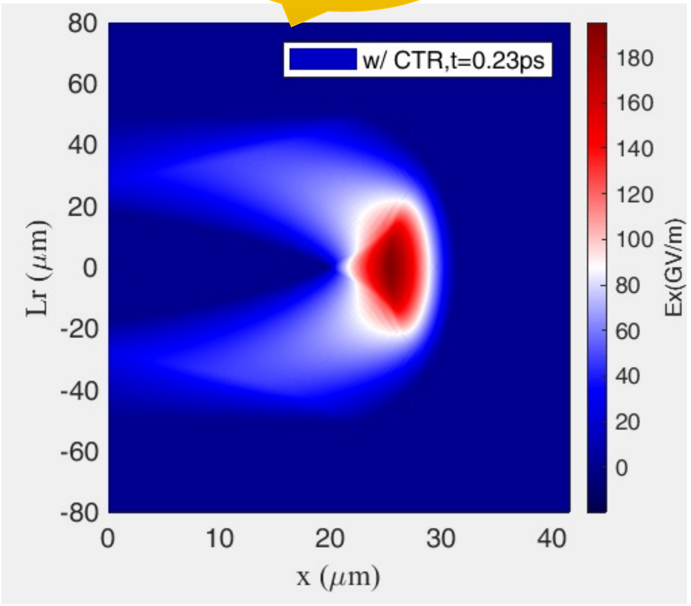
Positron acceleration

Coherent Transition Radiation (CTR)

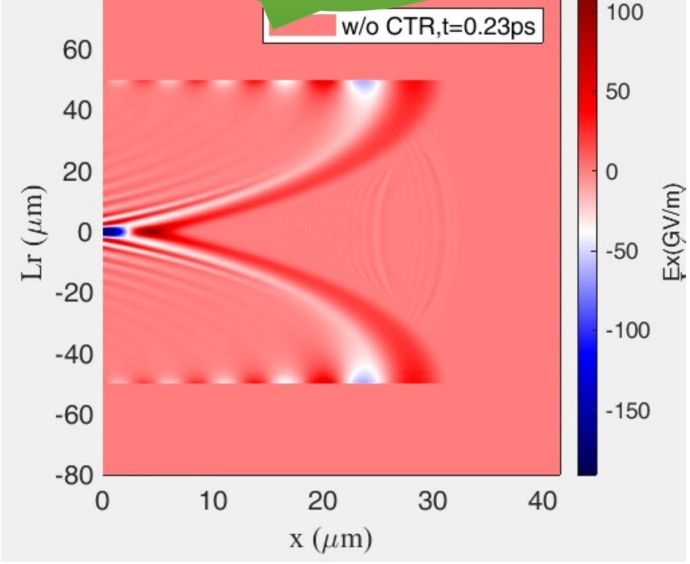




CTR



Electron beam?



According to the Lorentz back-transformation of coordinates, the **relativistic Poisson's equation** in the laboratory frame can be written as

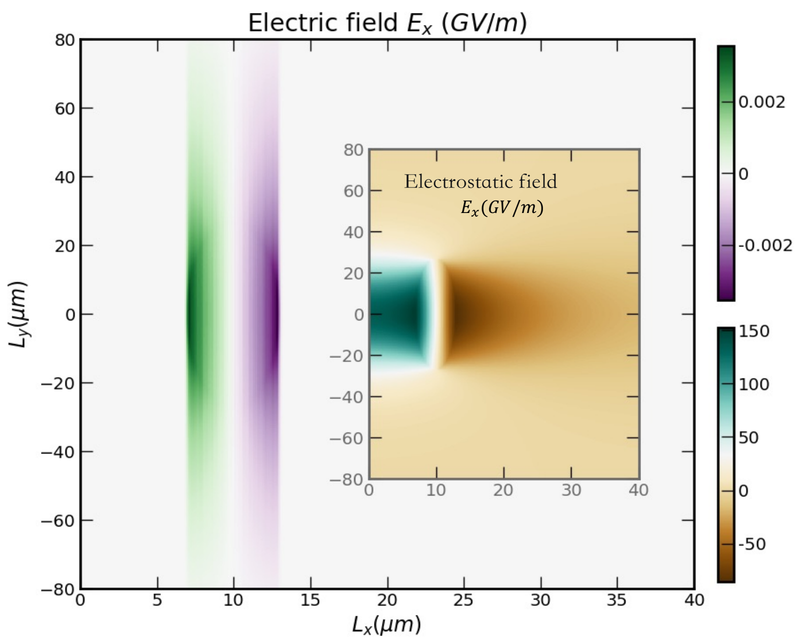
$$[\frac{1}{\gamma_0^2}\frac{\partial^2}{\partial^2_{x^2}}+\frac{\partial^2}{\partial^2_{y^2}}+\frac{\partial^2}{\partial^2_{z^2}}]\Phi=-\rho_b.$$

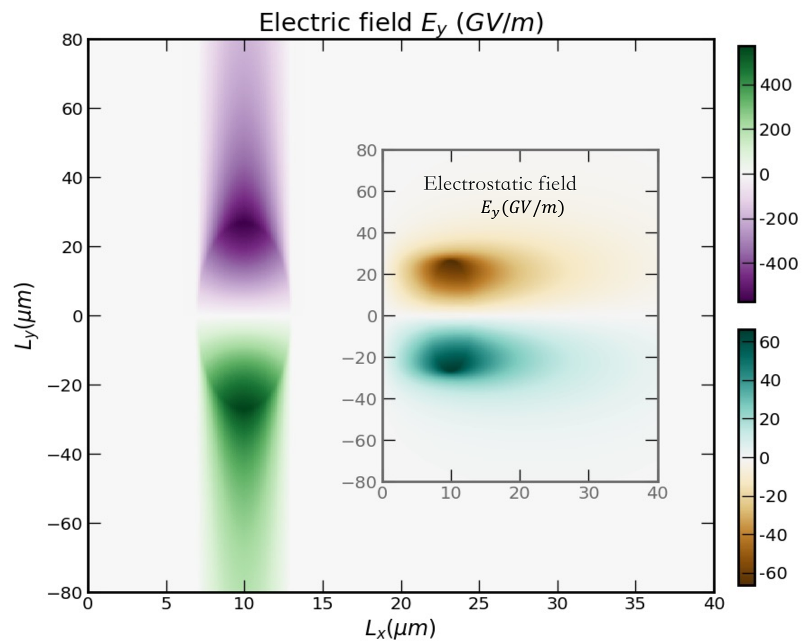
Initial current: $J(x,t=0)=\beta_0\rho_b\neq 0$

$$E_x=-\frac{1}{\gamma_0^2}\partial_x\Phi;$$

$$\sim\frac{1}{\gamma_0^2}(10^6)$$

$$E_y=-\partial_y\Phi.$$



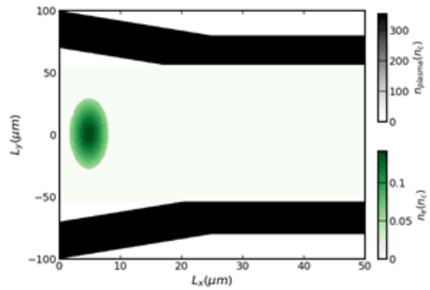


Self-consistent fields of the relativistic e⁻ beam in a plasma micro-tube

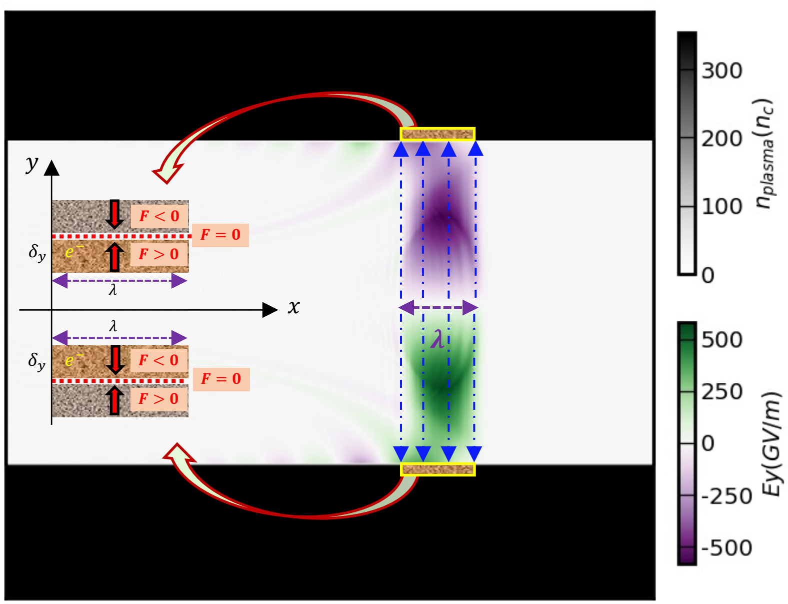
The strong transverse field E_y is applied to the plasma inner-wall in micro-tube and decays exponentially, which can be written as E_{yp}.

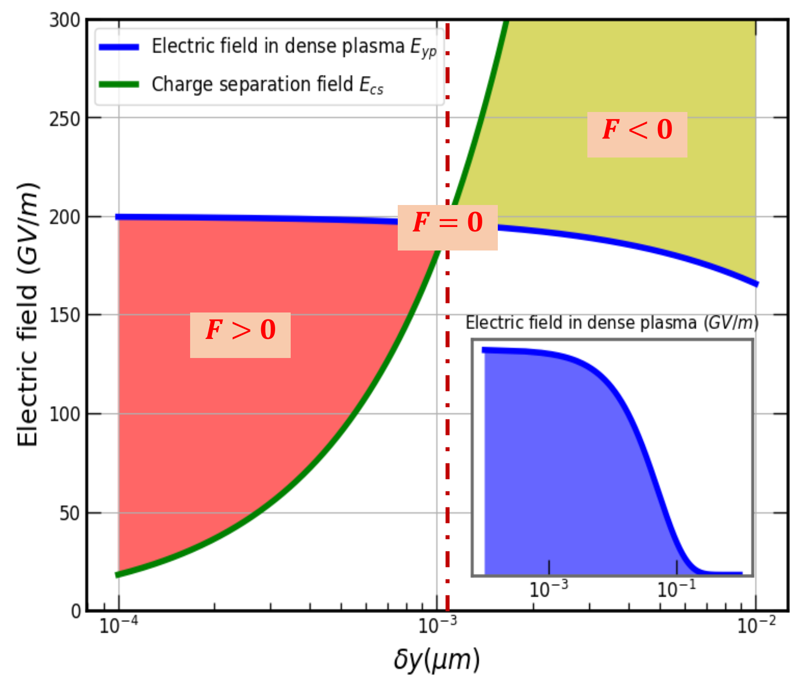
The strong charge separation field is proportional to the separation distance.

$$E_{yp} = E_0 e^{-\sqrt{k_x^2-1+\omega_{pe}^2}\,\delta y}, \delta y = y' - r$$



$$E_{cs} = \frac{e}{\varepsilon_0} \cdot \rho \cdot \delta y$$



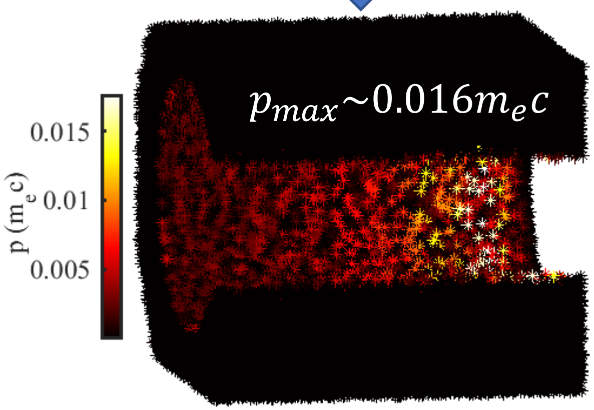


Intense continuous terahertz radiations from surface-nanofilm-plasma oscillations

The energy of the plasma electrons:

$$\int_0^{\delta_y} (eE_{yp} - eE_{cs})dy = (\gamma_p - 1)m_e c^2.$$

For $\delta_y = 1.1nm, \gamma_p = 1.0002, \beta_p = 0.0206.$



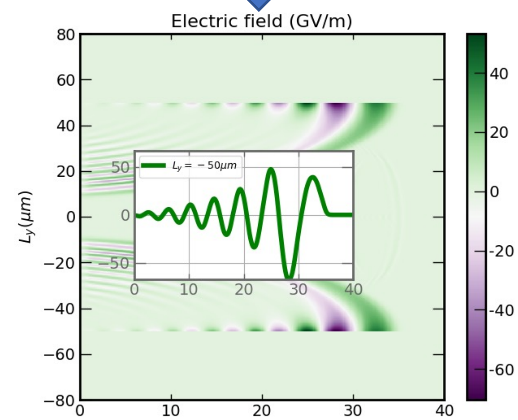
The radiation field E_{rad} of one electron can be obtained.

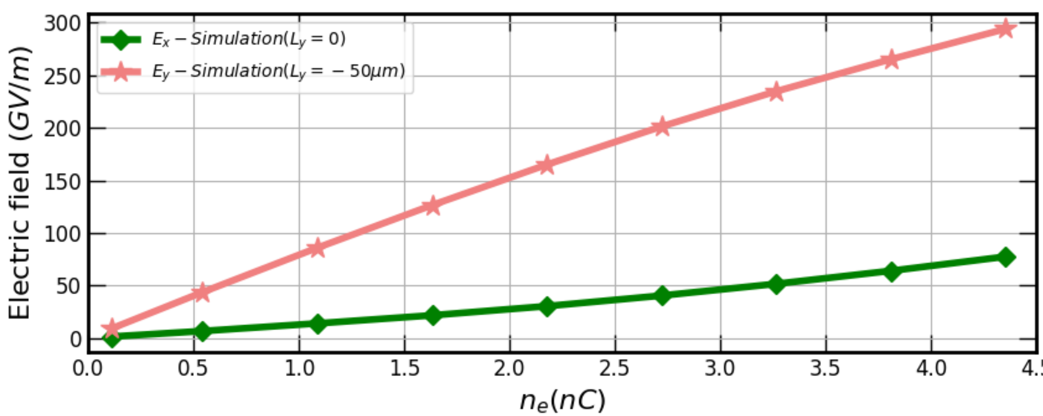
$$E_{rad} = \frac{e}{4\pi\varepsilon_0}\left[\frac{\dot{\vec{\beta}}_p}{c(1-\beta_p)^3\delta y}\right];$$

$$N_e = \rho\Delta x\Delta y\Delta z \quad \boxed{E_{tot} = N_e E_{rad}} \quad \sim几十GV/m$$

High-gradient

PIC Simulation

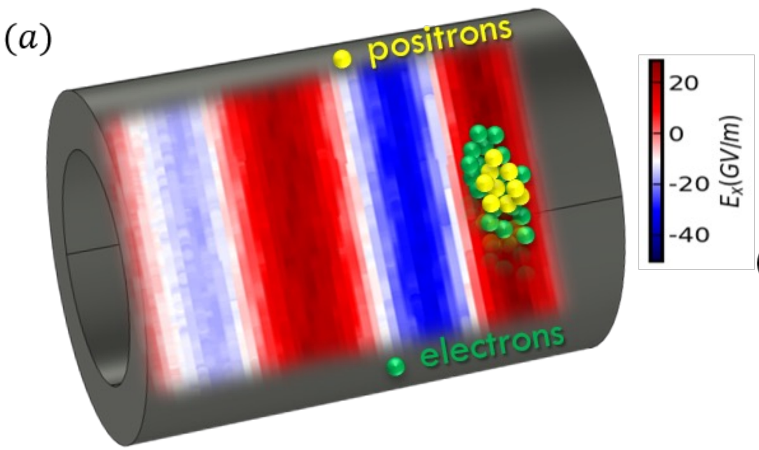




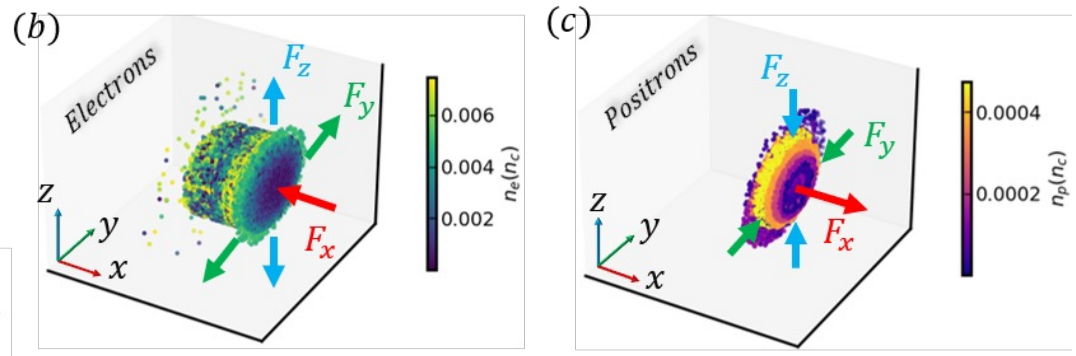
A novel scheme for positron bunch acceleration in an intense-field.

Due to the terahertz radiation from the oscillating electrons continuously, a field of about tens of GV/m, propagates synchronously with the electron beam and accelerates the positron bunch in a stable phase.

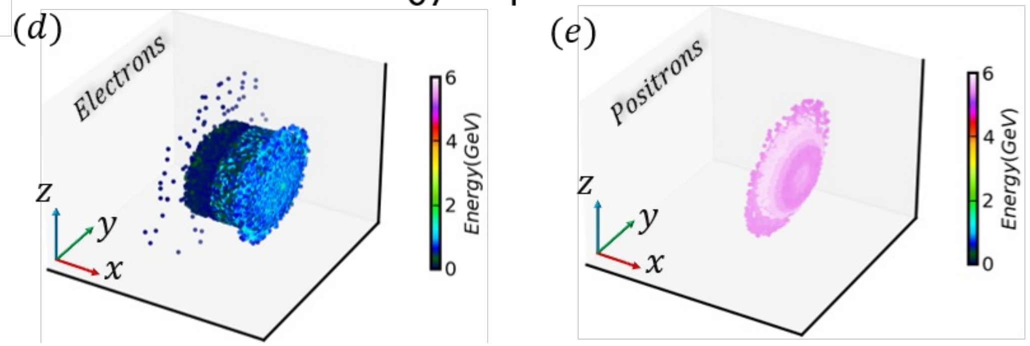
The schematic diagram.



The density of particles



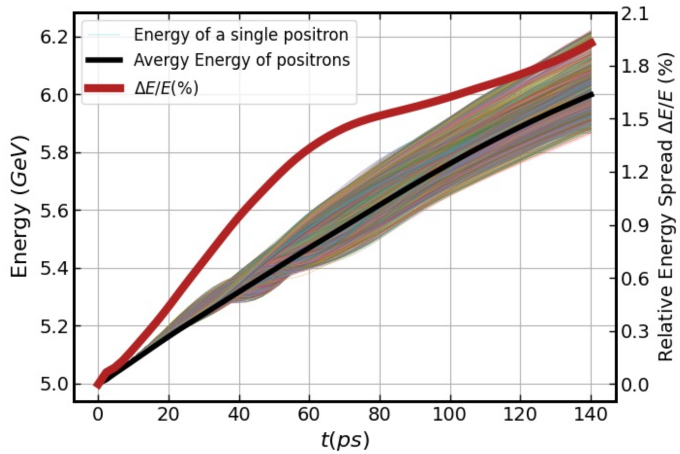
The energy of particles



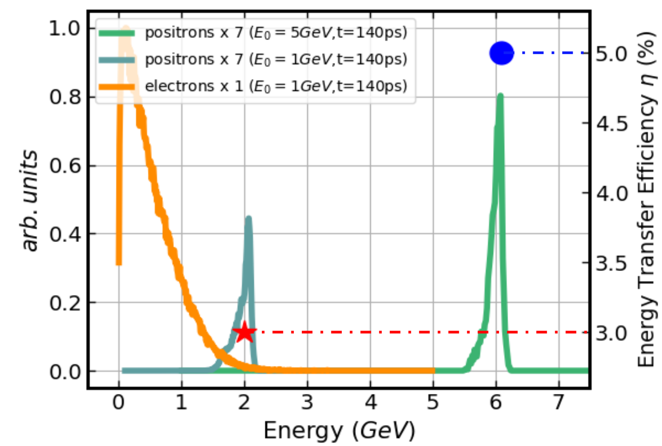
The longitudinal acceleration field is ultra-intense and of the order of tens of GV/m, which is uniform and stable, and has a high tolerance for the off-axis injection positron bunch.

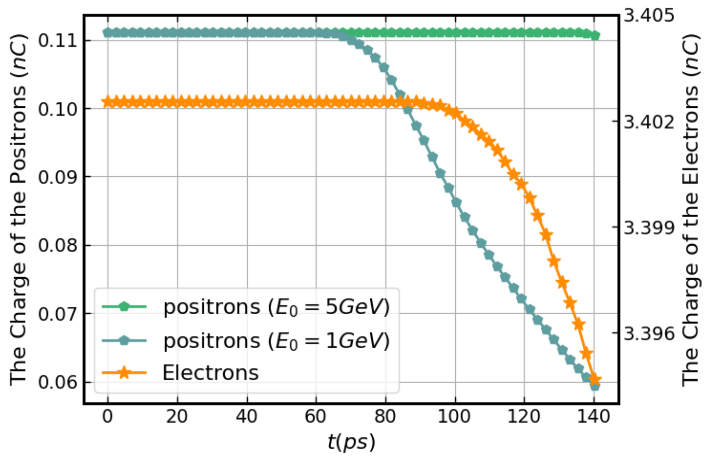
The simulation results of e^+ acceleration in a micro-tube.

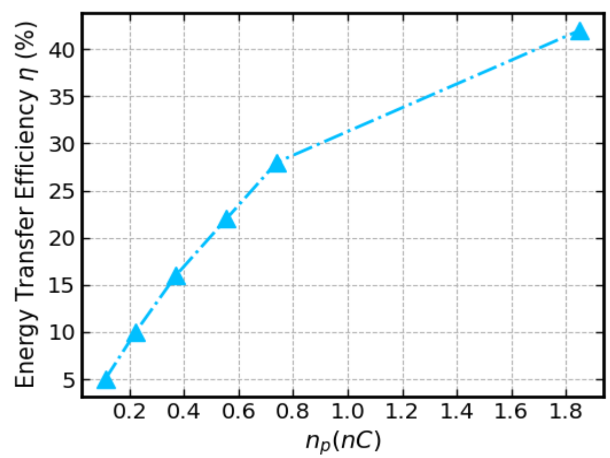
The energy spread **<2%**



Energy gain **1 GeV /~ 4 cm**





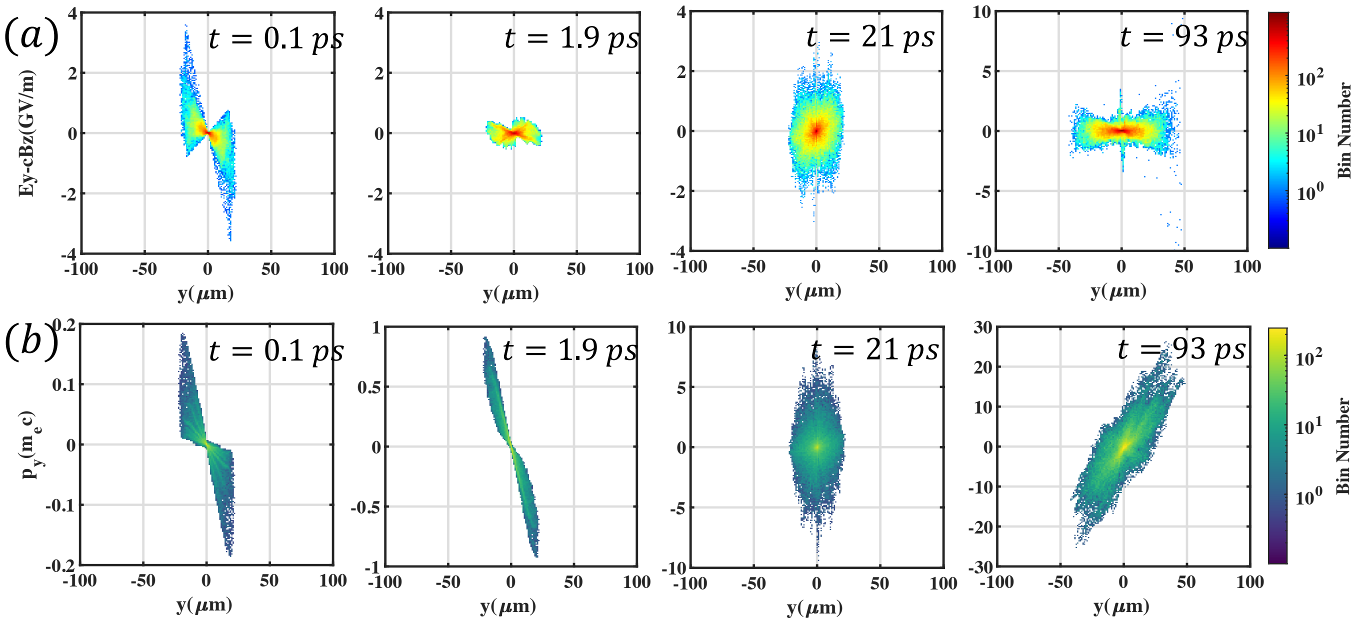


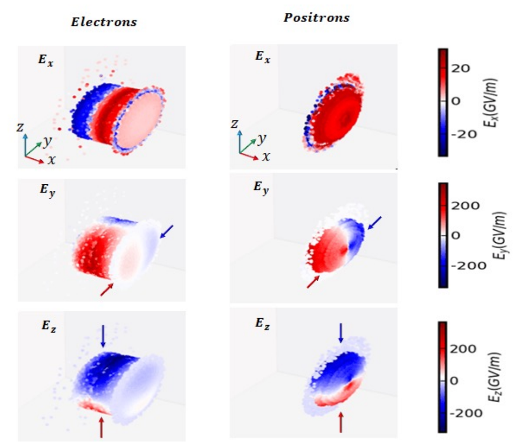
$$\eta = \frac{\delta E_p \cdot Q_p}{\delta E_e \cdot Q_e},$$

The energy transfer efficiency of about 5% to 22% corresponding to the initial charge of the positron bunch of about 0.1 nC to 0.56 nC.

Evolution of transverse field in the y direction

Transverse field $(E_y - cB_z)$ distribution experienced by positron bunch during acceleration of plasma micro-tube.

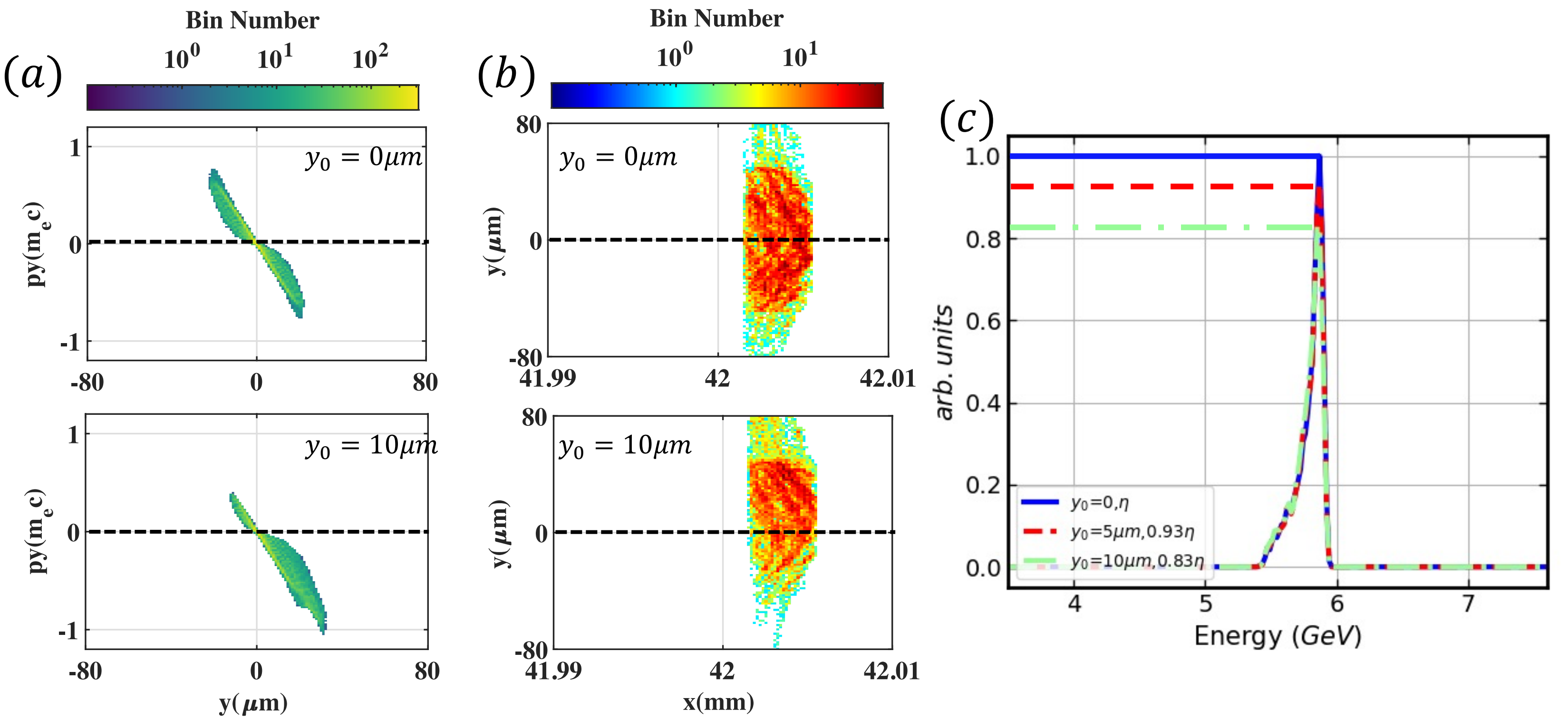




The transverse self-field of the relativistic driven electron beam can provide a transverse focusing force on the positron bunch. The process from focusing to short-term stabilization and finally weak defocusing until the transverse field is zero.

Analysis of transverse off-axis injection of positron bunch

The influence of the injection deviation of positron bunch in the y direction on the final acceleration result.



The energy transfer efficiency of positron bunch decreased by about 17% when the positron bunch deviated by 10 μm transversely at the initial time.

总结与展望

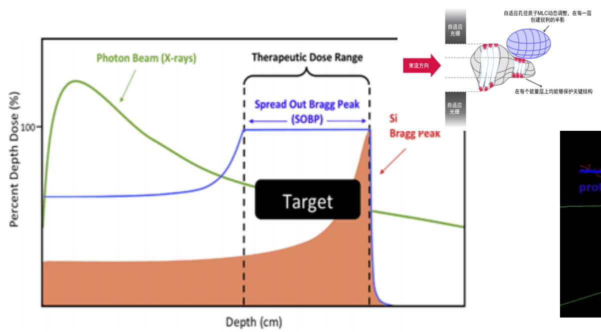
◆ Positron acceleration

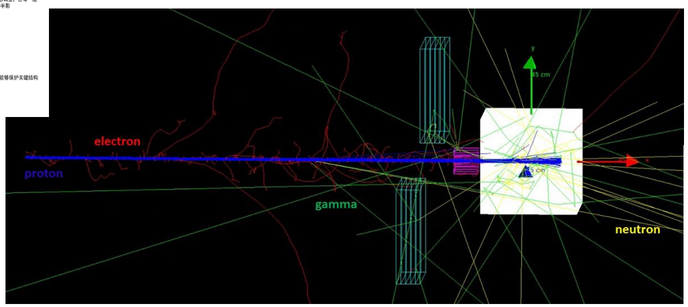
[1] Positron acceleration with coherent transition radiation in a dense plasma-channel.

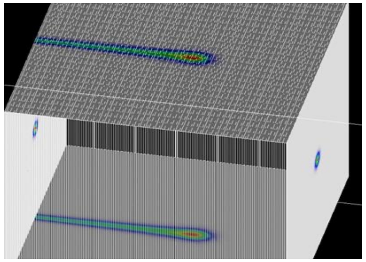
[2] Novel positron acceleration by intense co[illegible]us terahertz radiations from surface-nanofilm-plasma oscillations in a micro-tube.

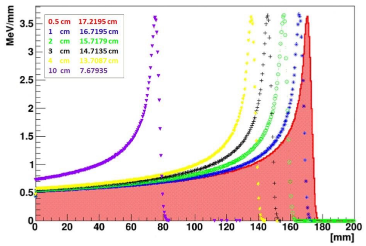
◆ Treatment Planning System (TPS)

IMPT









Flash 放射治疗机制 (110-120Gy/s)

◆ Tau g-2

Tau (τ lifetime $\sim 10^{-13}\ s$)

Precision measurements of electromagnetic couplings are foundational tests of quantum electrodynamics(QED) and powerful probes of **beyond the Standard Model (BSM)** physics.

$$\frac{m_\tau^2}{m_\mu^2} \sim 280 \ (\delta a_l \sim m_l^2 / M_S^2)$$

调研 LHC/CLIC/LEP a_τ ---- **CEPC**

Thanks for your attention！