

Electron cloud densities at the center of the FCC-ee dipoles

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Acknowledgments:

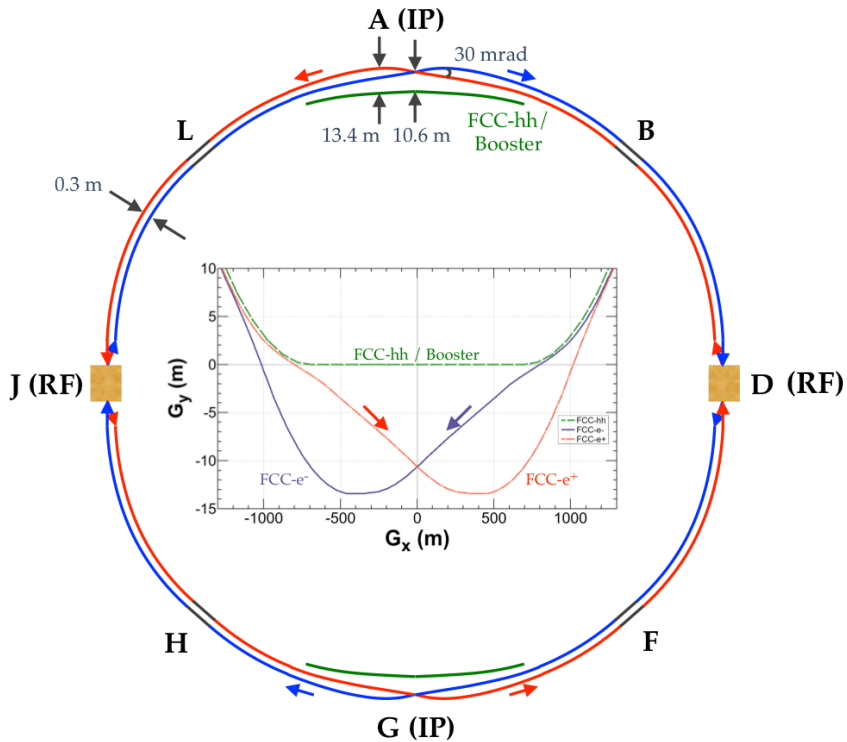
F. Zimmermann, R. Kersevan, K. Ohmi, G. Iadarola, K. Oide and S. Ogur

FCC-ee Collider and Beam Parameters

beam energy [GeV]	45.6
bunch spacing [ns]	10, 12.5, 15, 17.5, 20
bunches per train	150
trains per beam	1
circular beam pipe radius [mm]	35
r.m.s. bunch length (σ_z) [mm]	3.5
h. r.m.s. beam size (σ_x) [μm]	120
v. r.m.s. beam size (σ_y) [μm]	7
number of particles / bunch	1.7×10^{11}
bend field [T]	0.01415
secondary emission yield (SEY) (Furman-Pivi model)	1.1, 1.2, 1.3, 1.4
photoelectrons generation rate $n'_{e(\gamma)}$	1e-3, 1e-4, 1e-5, 1e-6



Frank Zimmermann, 'FCC-ee design overview'
 FCC Week 2019 Brussels, June 2019
<https://indico.cern.ch/event/727555/>



$$n'_{e(\gamma)} = Y_\gamma \frac{dN_\gamma}{dz}$$

↓

$$Y_\gamma \approx 0.1$$

(photo-electron yield coefficient)

Number of photoelectrons emitted per length:

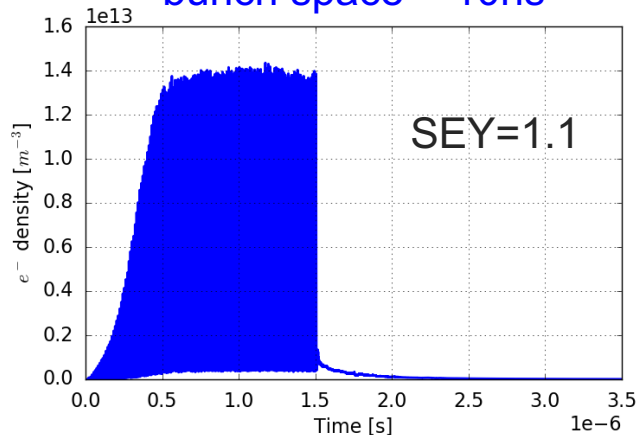
$$\frac{dN_\gamma}{dz} = \frac{5\alpha\gamma}{2\sqrt{3}\rho}$$

- $\alpha \approx 1/137$, fine structure constant
- $\gamma \approx 10^5$, the Lorentz factor
- $\rho \approx 11000$ [m] , radius of curvature of the particle path

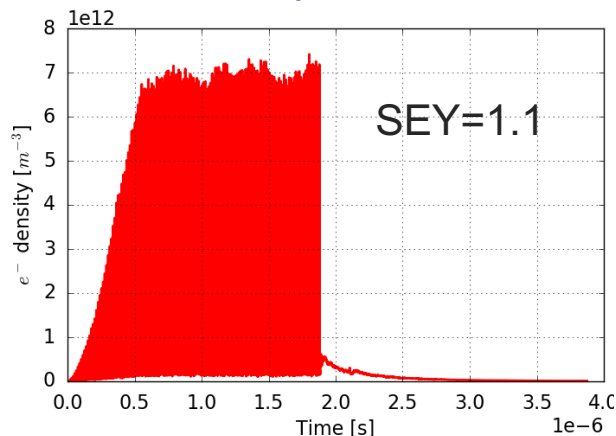
e^- density at the center of the dipole chamber

$$n'_{e(\gamma)} = 1e-3$$

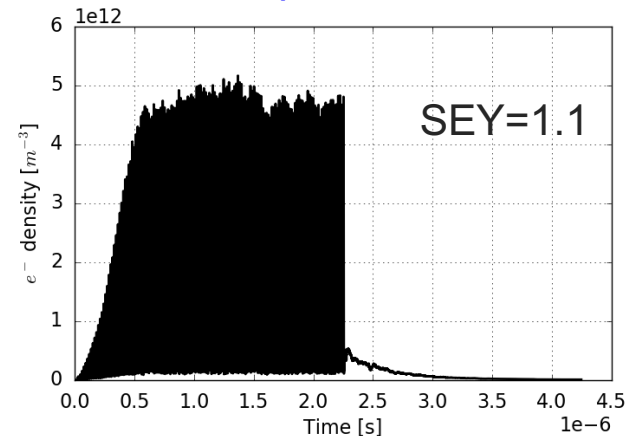
bunch space = 10ns



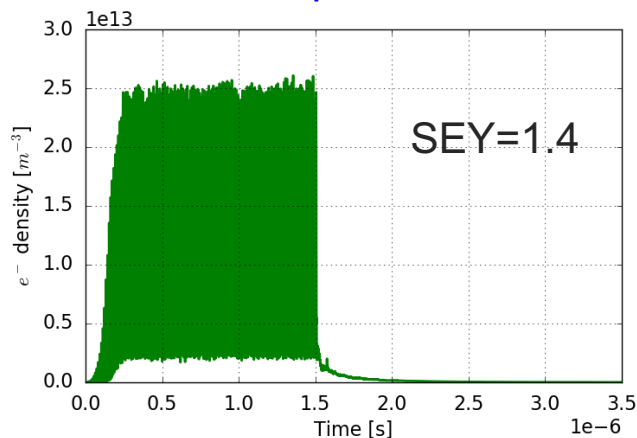
bunch space = 12.5ns



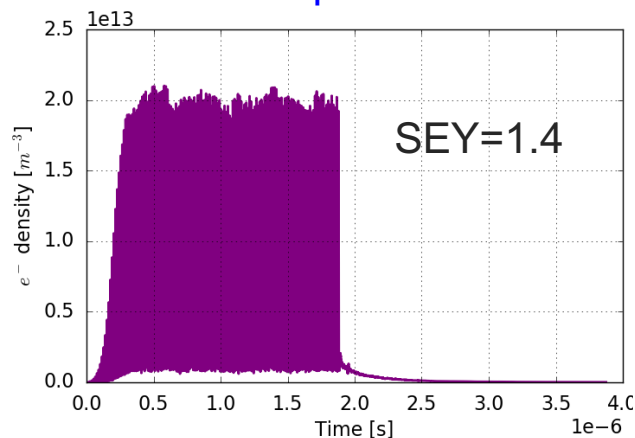
bunch space = 15ns



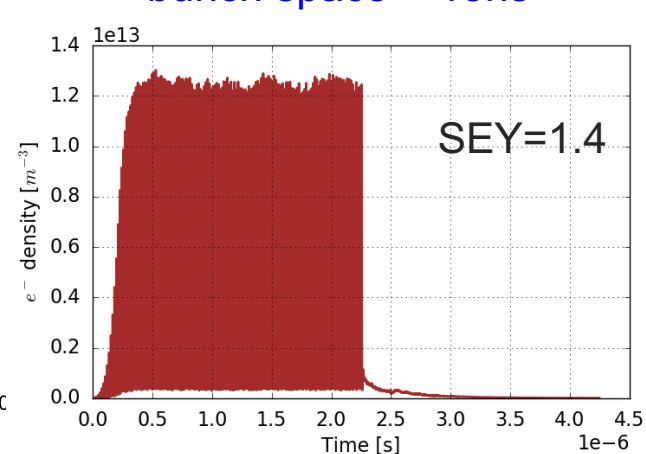
bunch space = 10ns



bunch space = 12.5ns



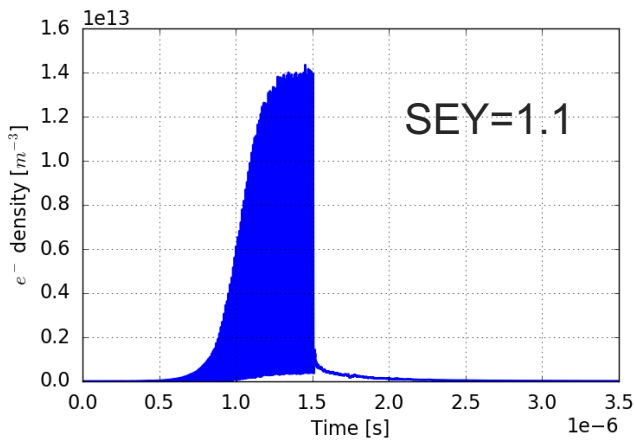
bunch space = 15ns



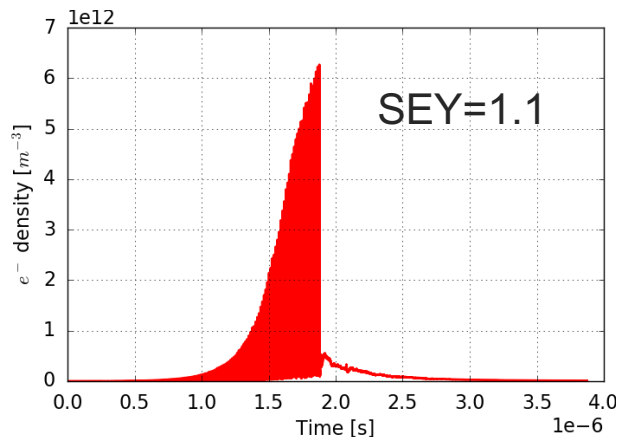
e^- density at the center of the dipole chamber

$$n'_{e(\gamma)} = 1e-6$$

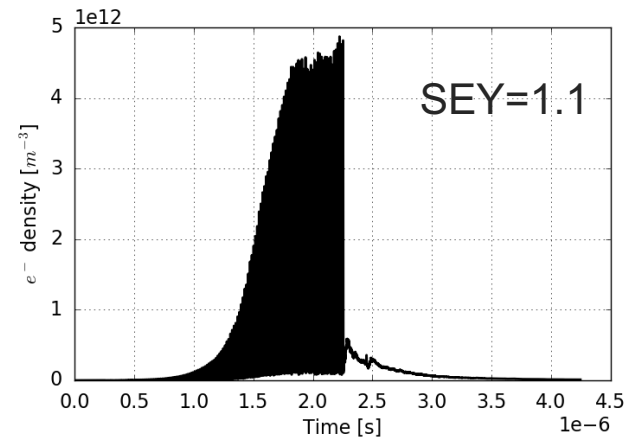
bunch space = 10ns



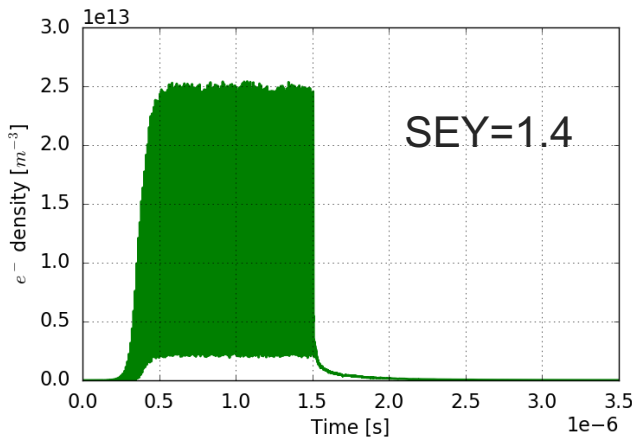
bunch space = 12.5ns



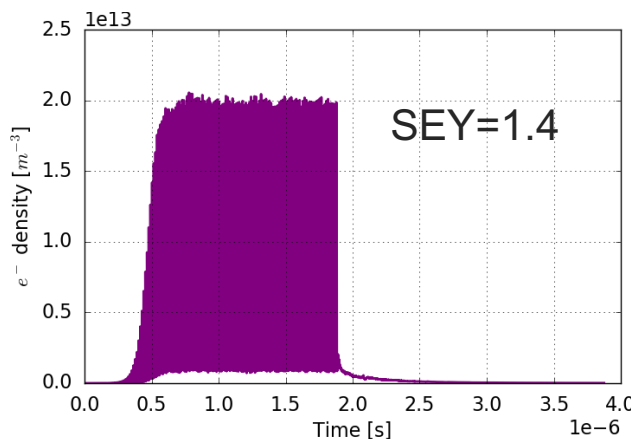
bunch space = 15ns



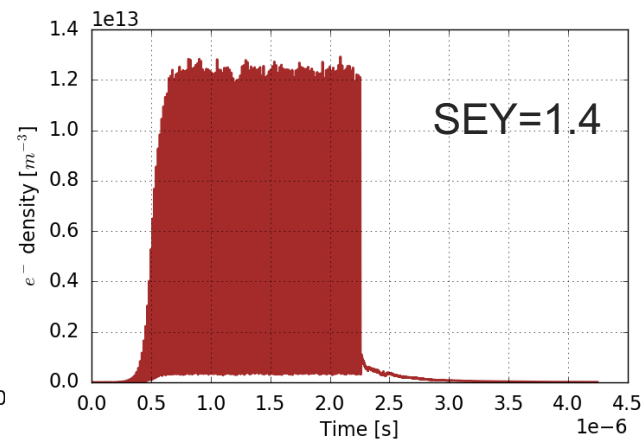
bunch space = 10ns



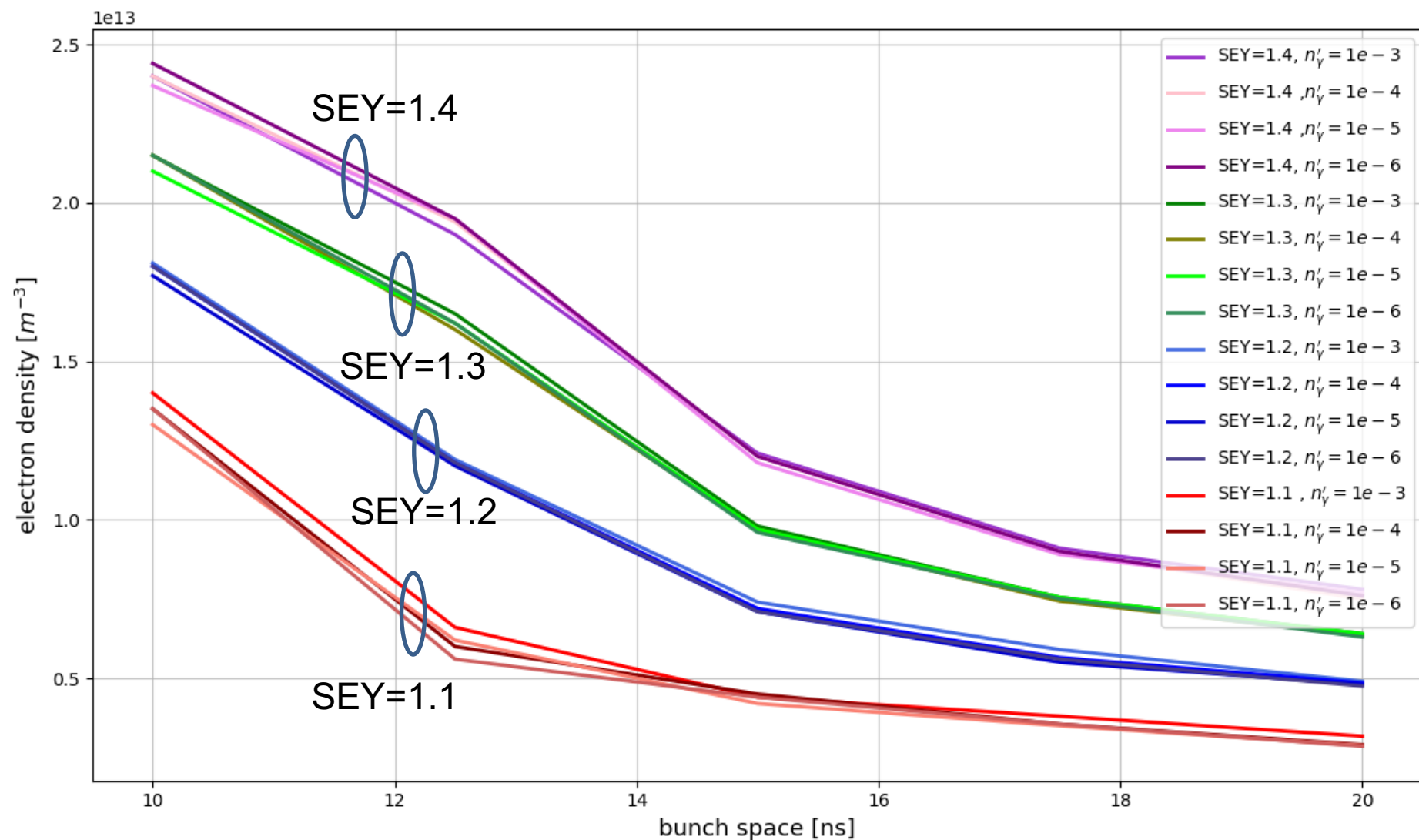
bunch space = 12.5ns



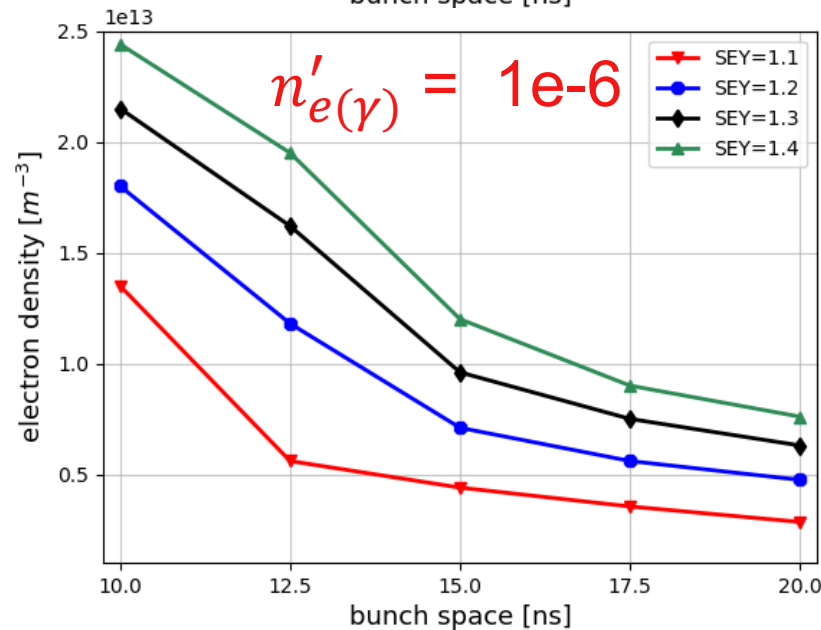
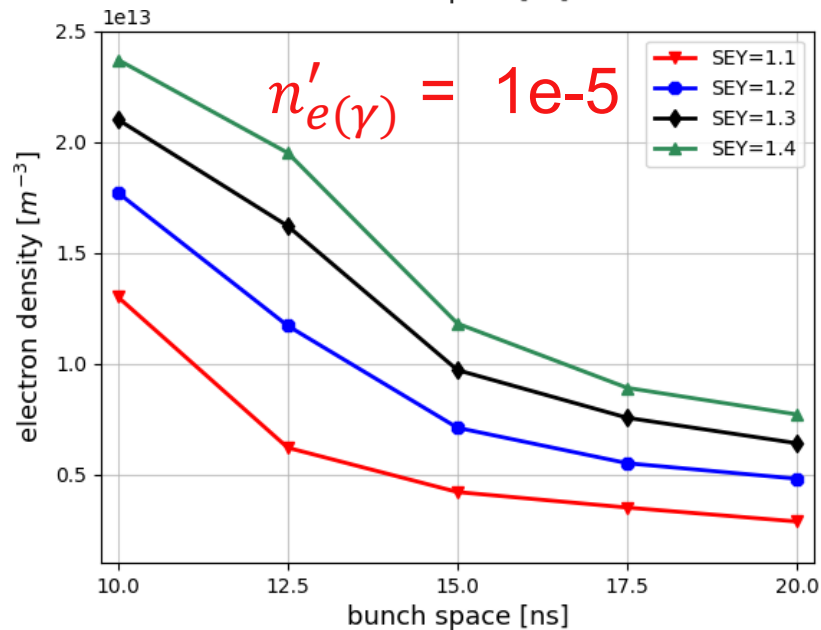
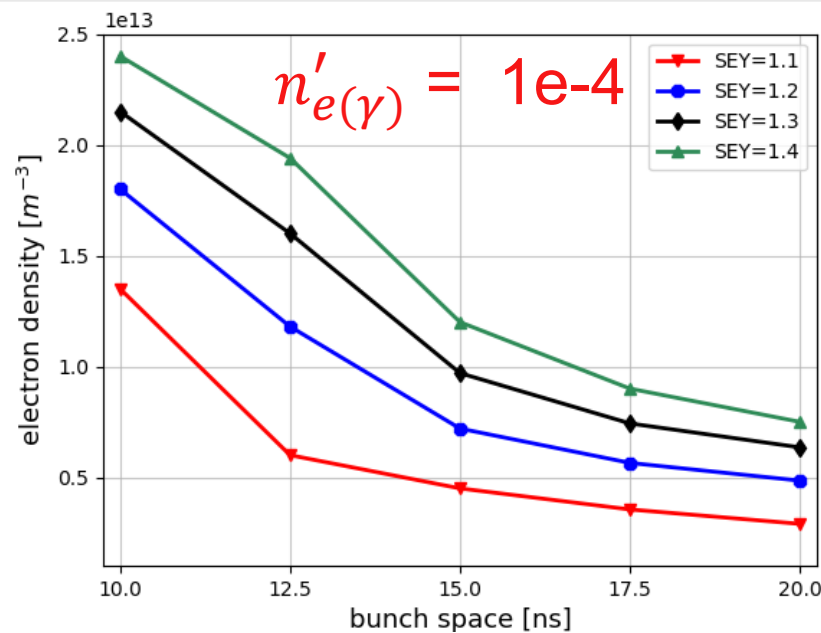
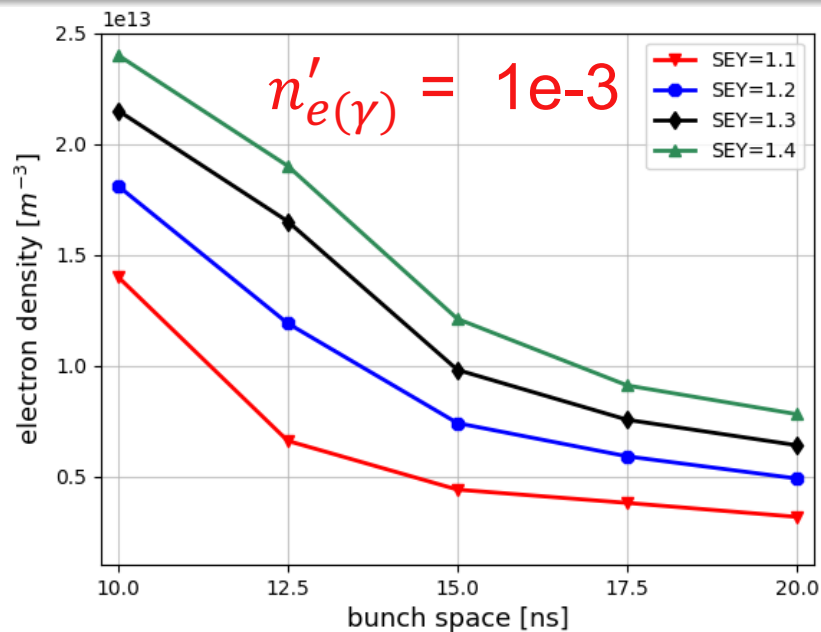
bunch space = 15ns



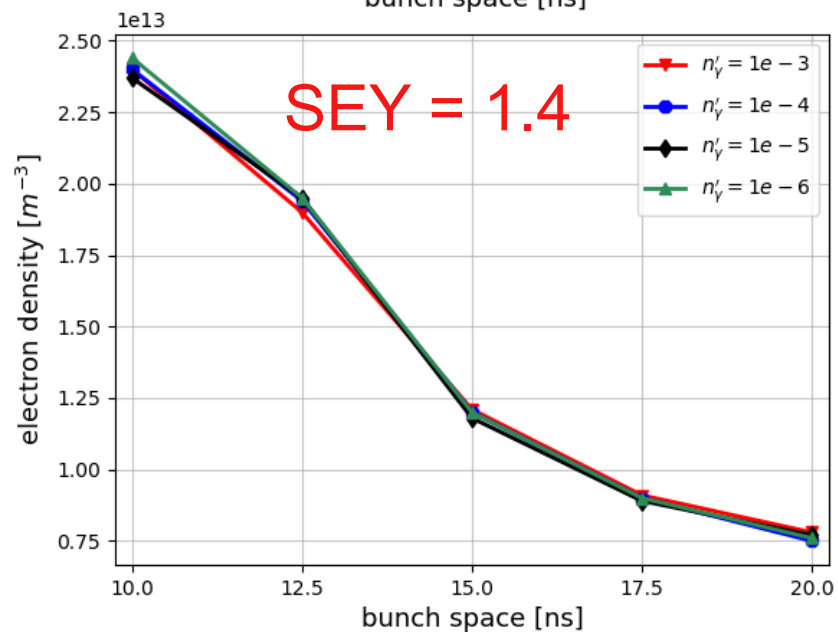
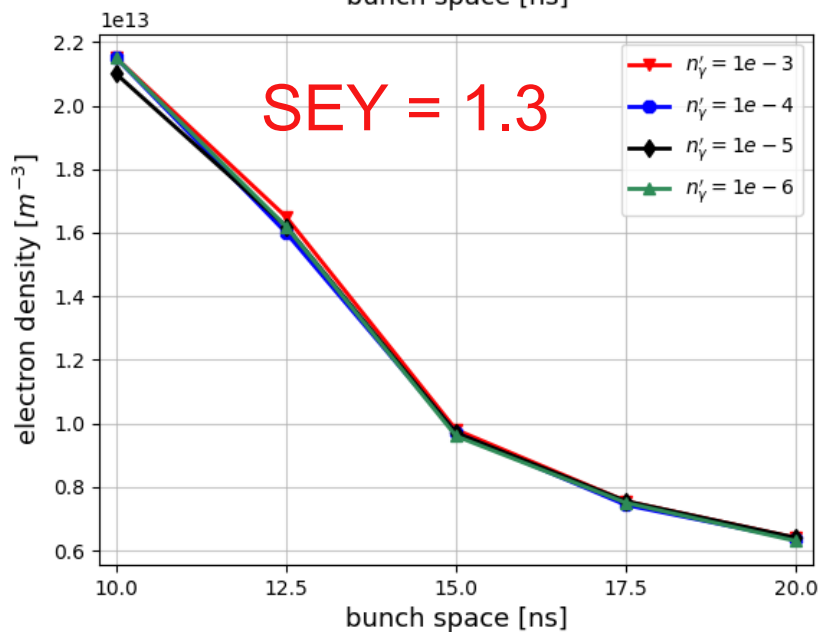
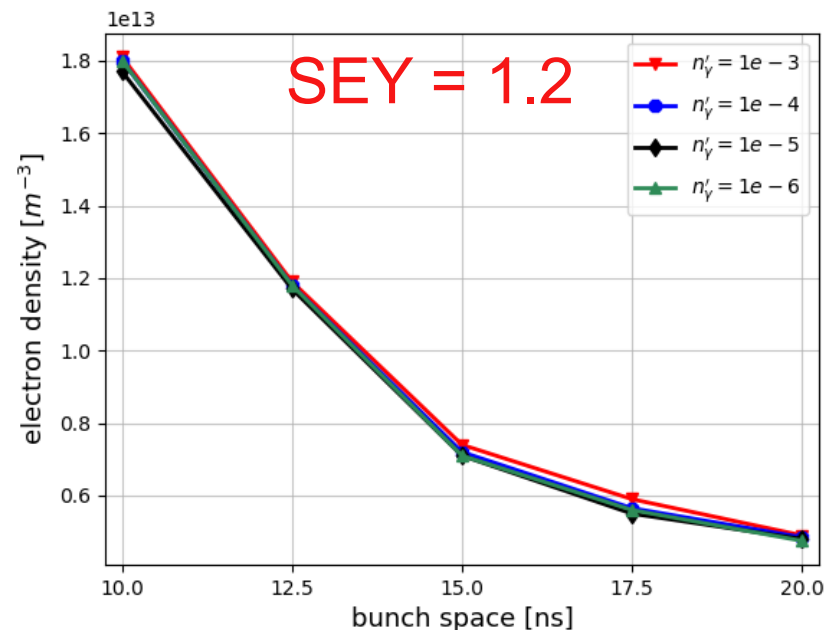
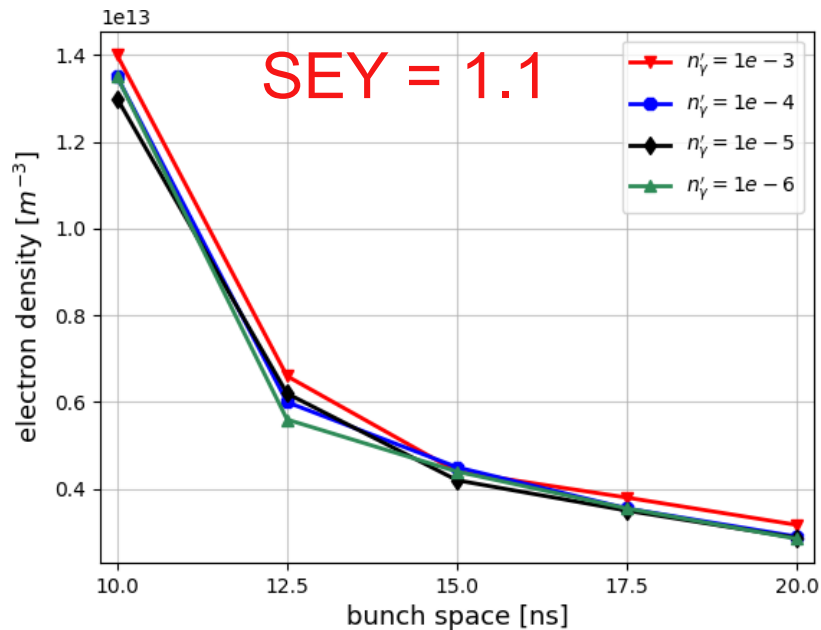
Center e^- density for various SEY, $n'_{e(\gamma)}$, bunch spacings



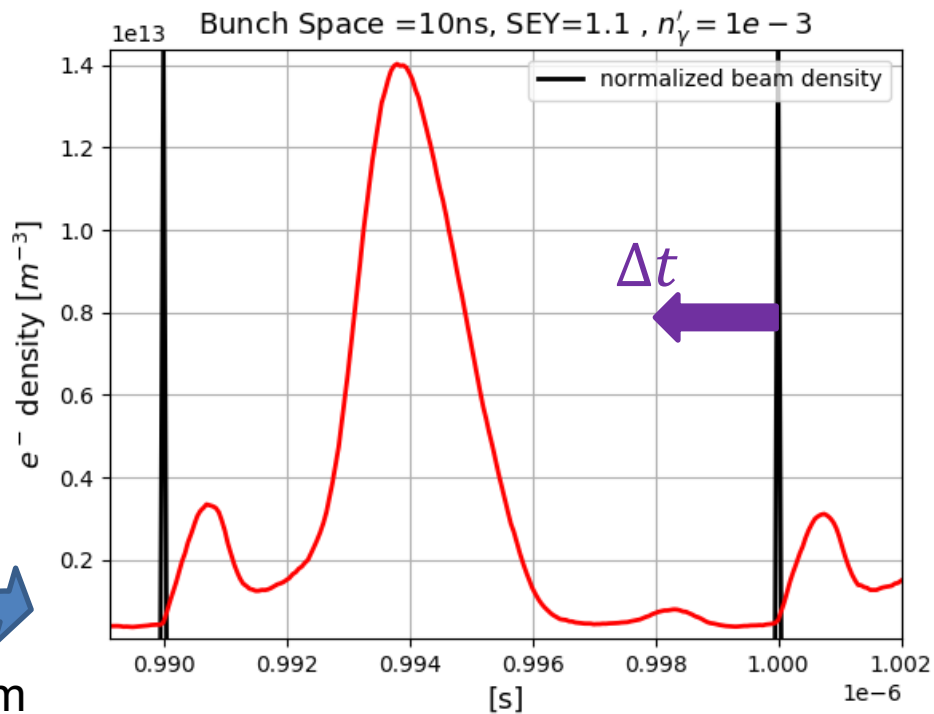
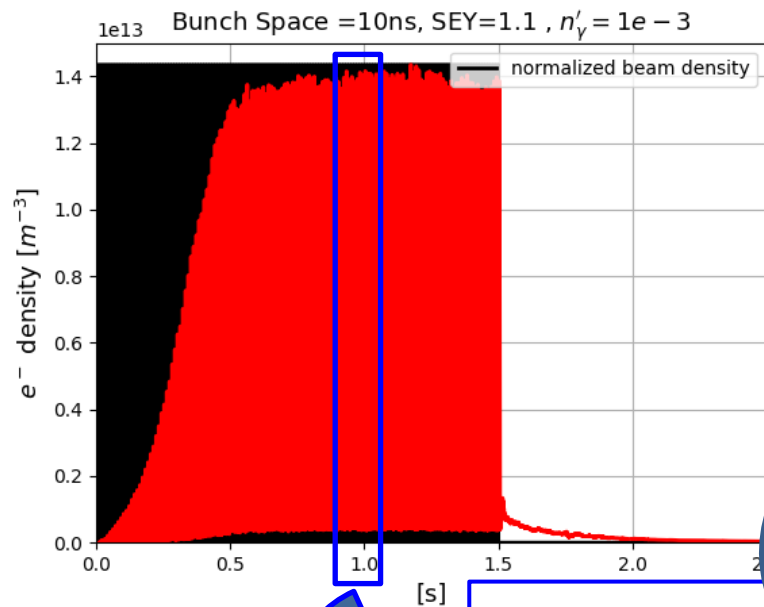
Center e^- density for various SEY, $n'_{e(\gamma)}$, bunch spacings



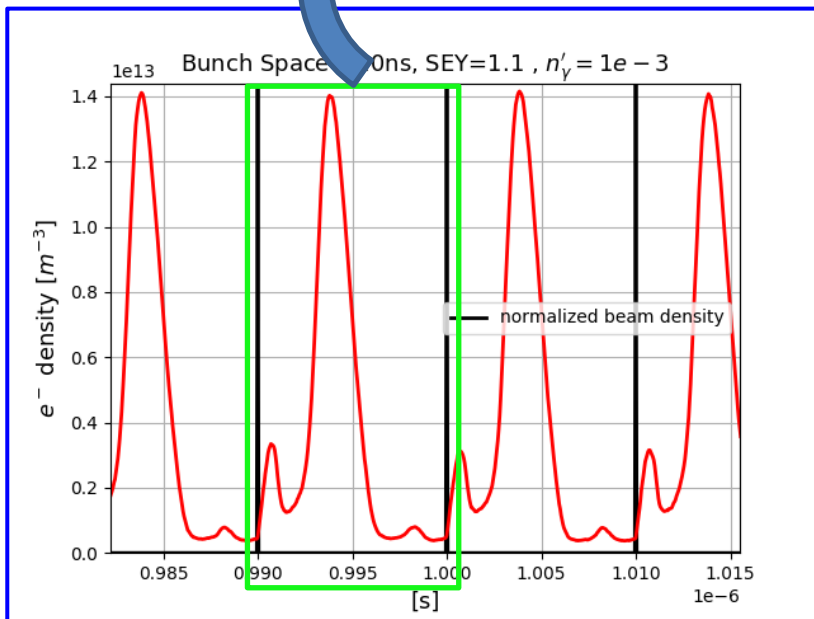
Center e^- density for various SEY, $n'_{e(\gamma)}$, bunch spacings



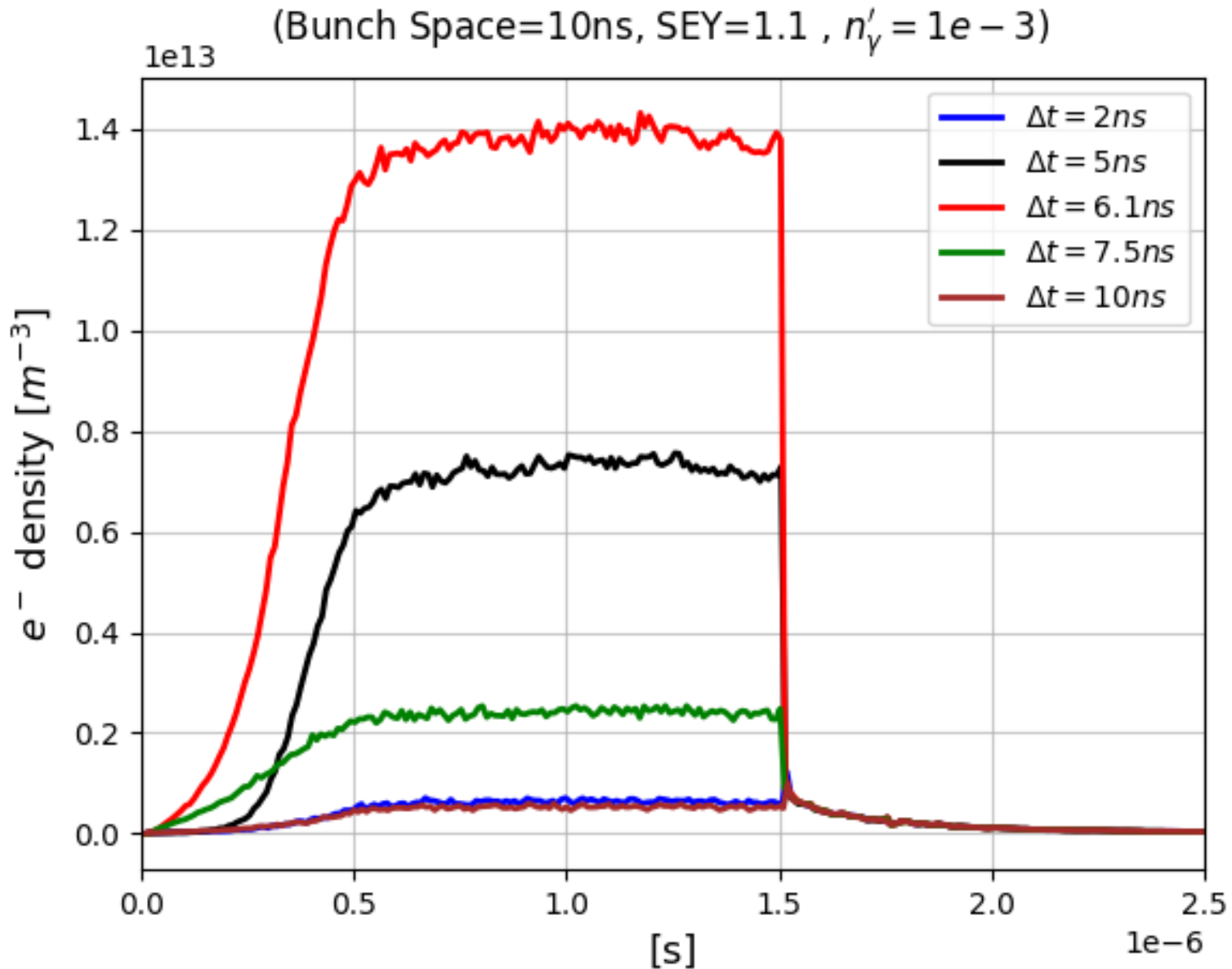
Distribution



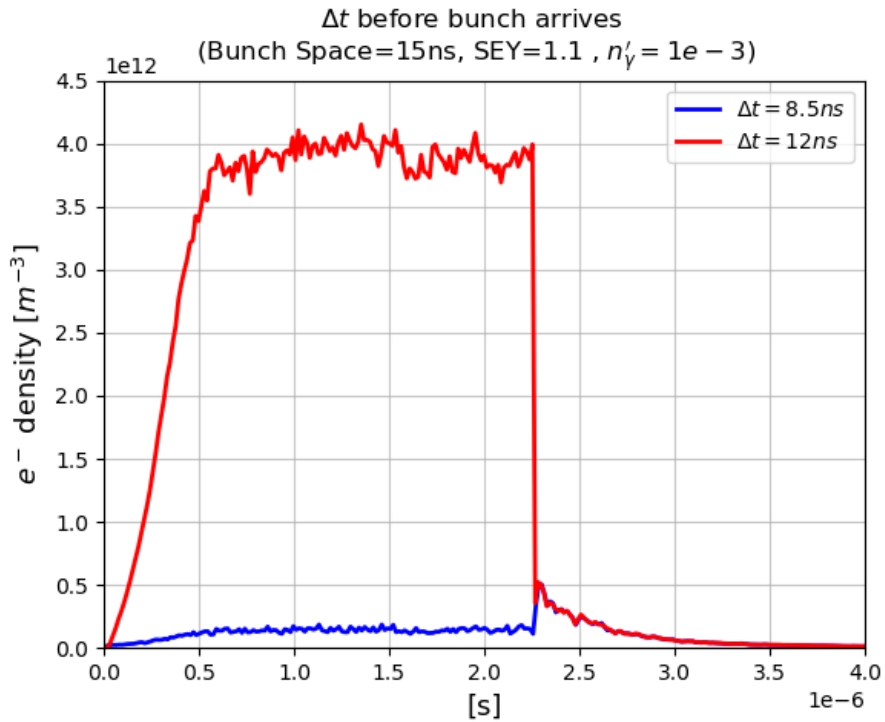
zoom



Densities Δt before bunch arrives



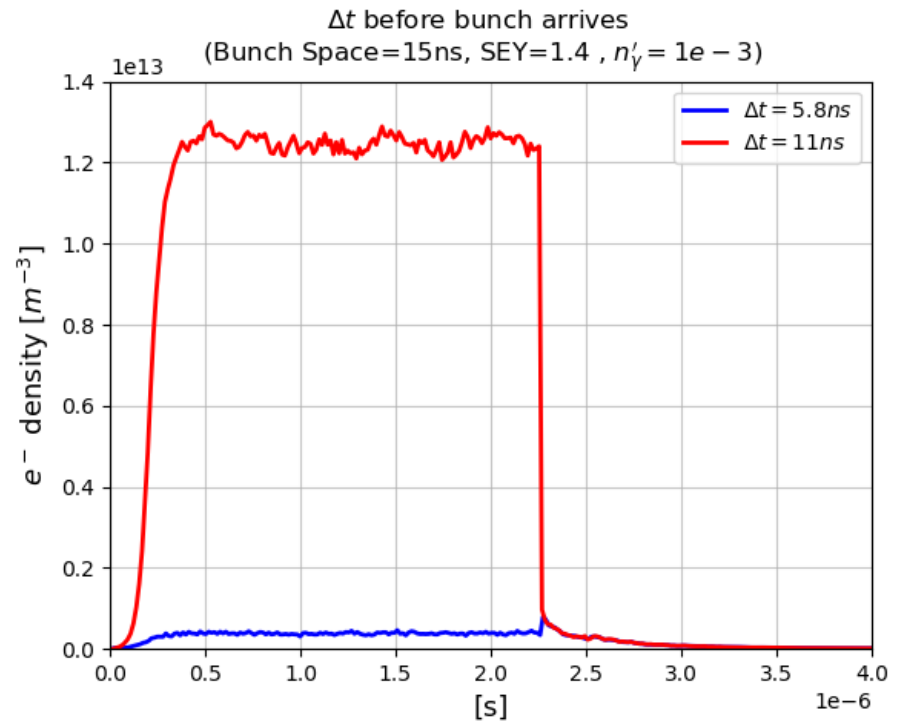
Max. & Min for 15ns and $n'_{e(\gamma)} = 1e-3$



SEY=1.1

Max $\approx 3.8 \times 10^{12}$

Min $\approx 2 \times 10^{11}$



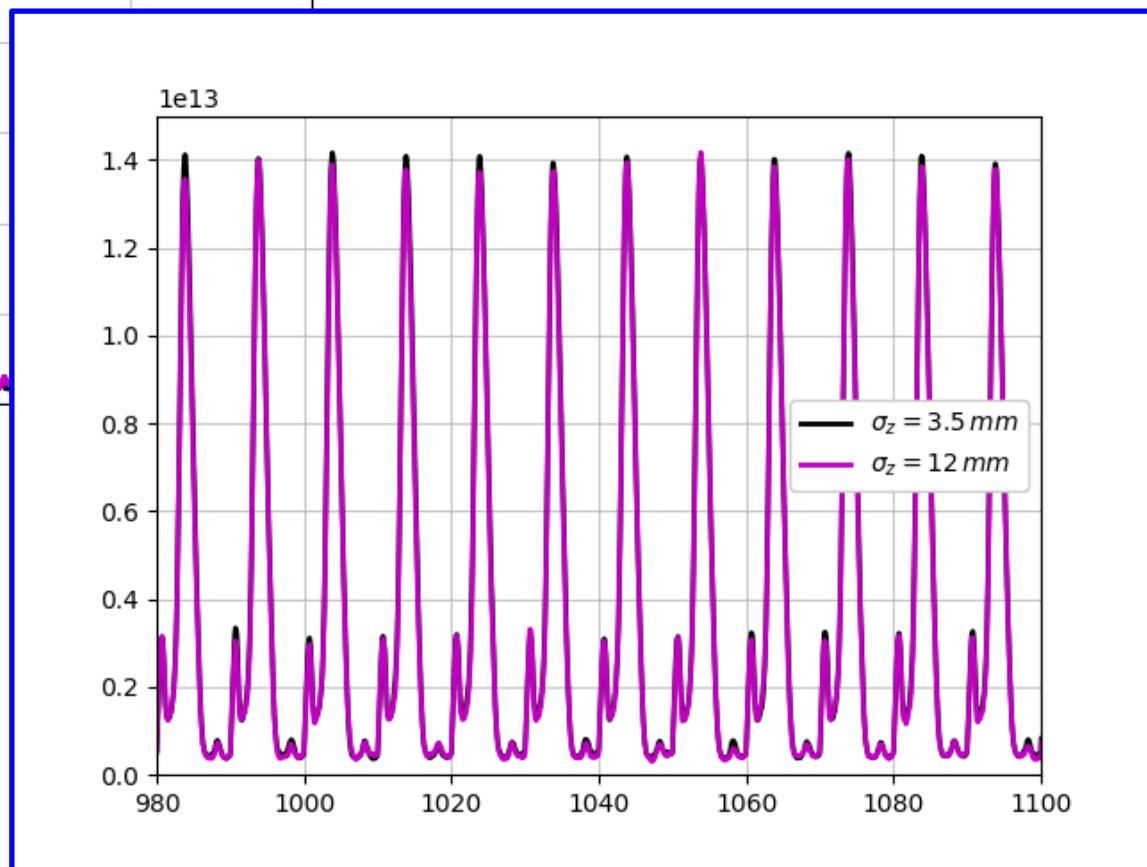
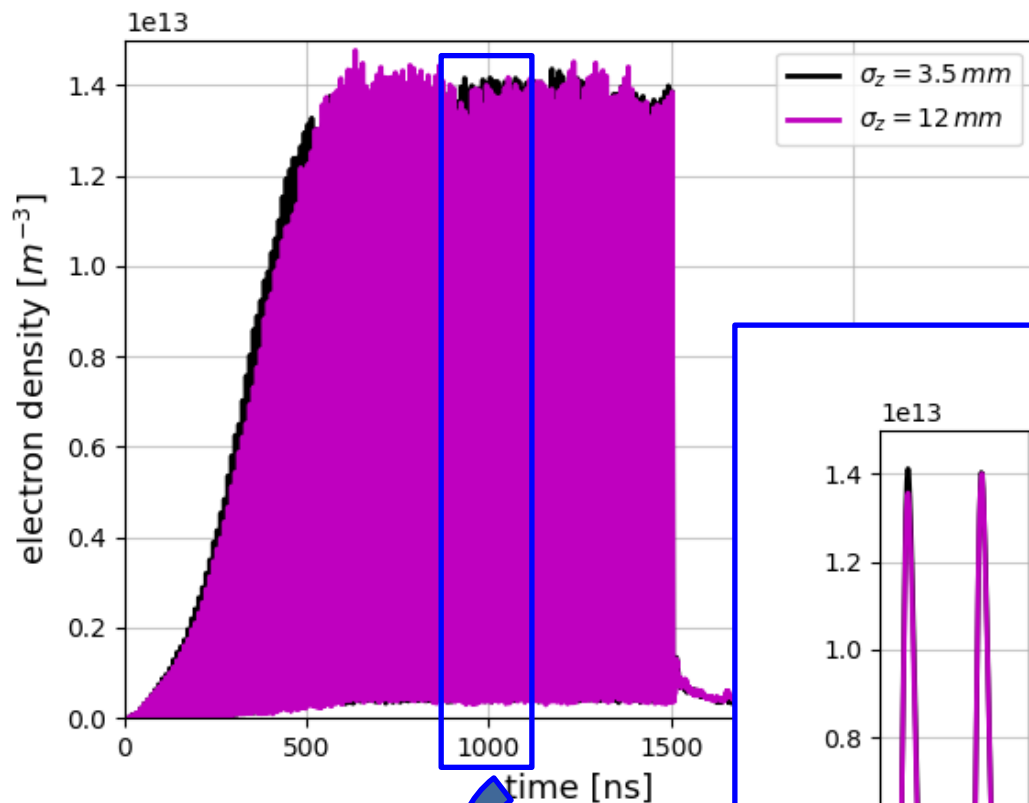
SEY=1.4

Max $\approx 1.25 \times 10^{13}$

Min $\approx 5 \times 10^{11}$

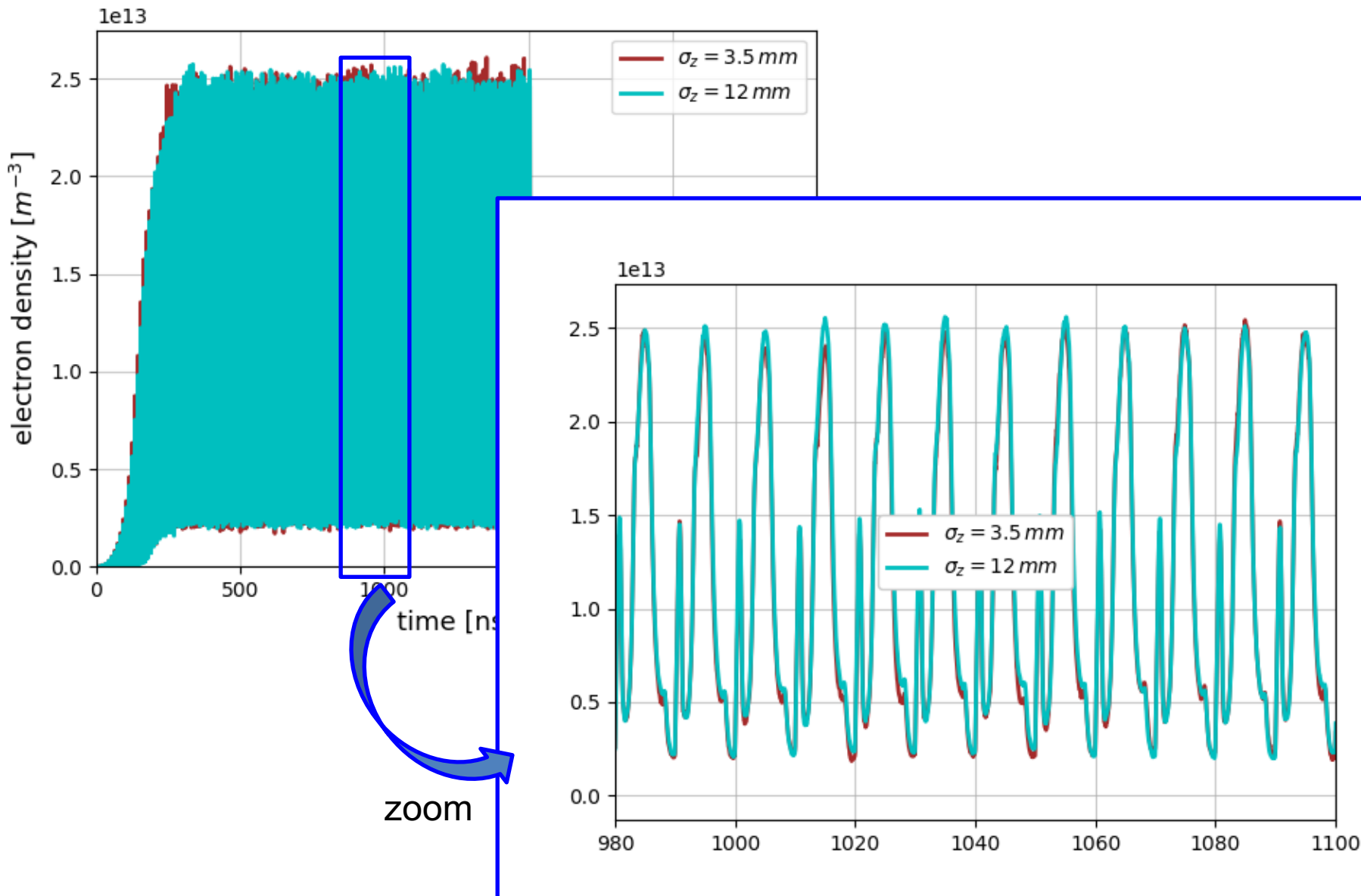
Center density for different σ_z (SEY=1.1)

FCC-ee Dipole Center Density (SEY=1.1, $n'_y = 1e-3$)

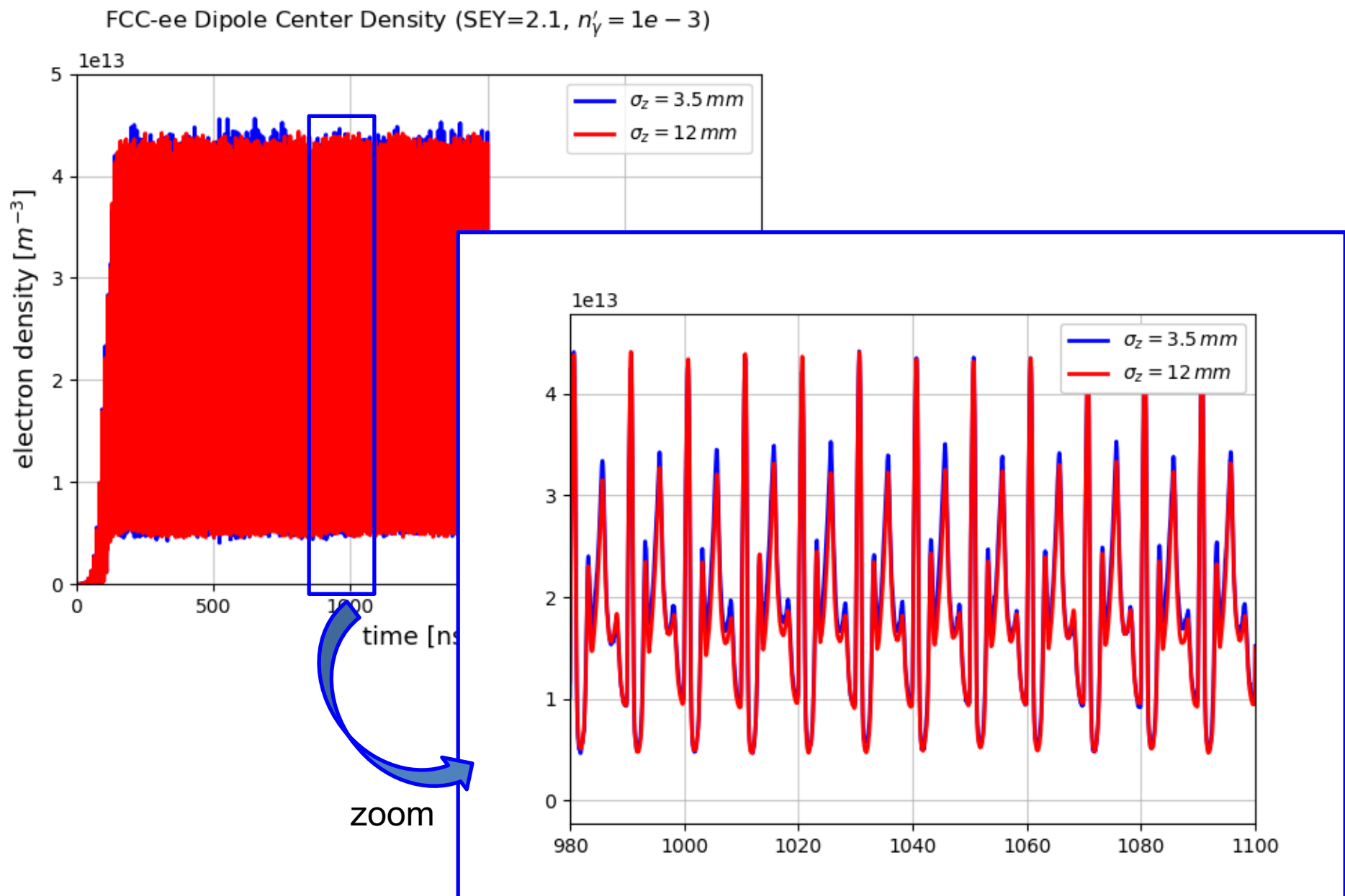


Center density for different σ_z (SEY=1.4)

FCC-ee Dipole Center Density (SEY=1.4, $n'_y = 1e-3$)



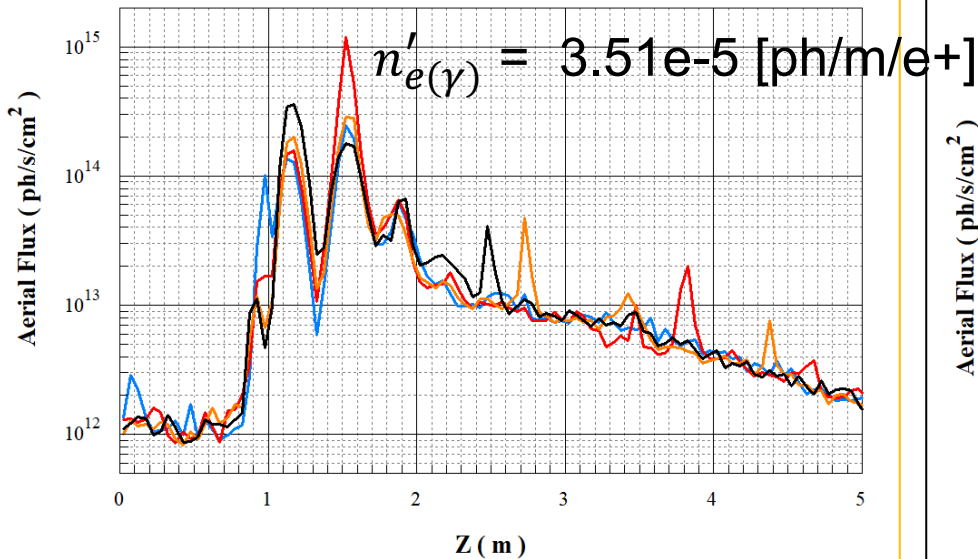
Center density for different σ_z (SEY=2.1)



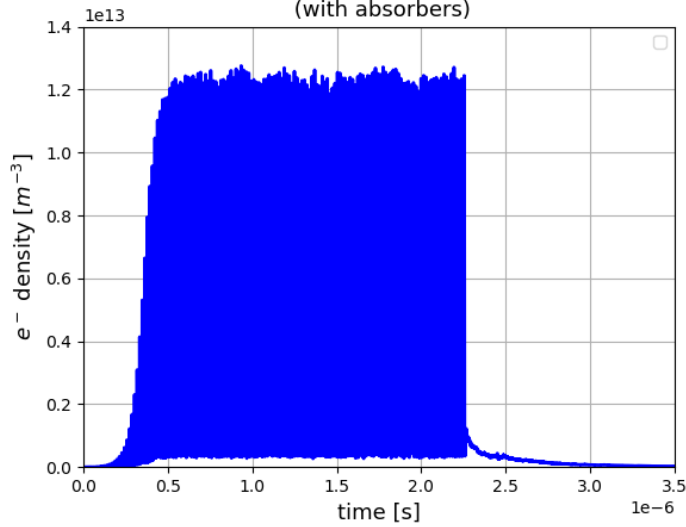
Photon Fluxes with and without Absorbers

with the courtesy of R. Kersevan

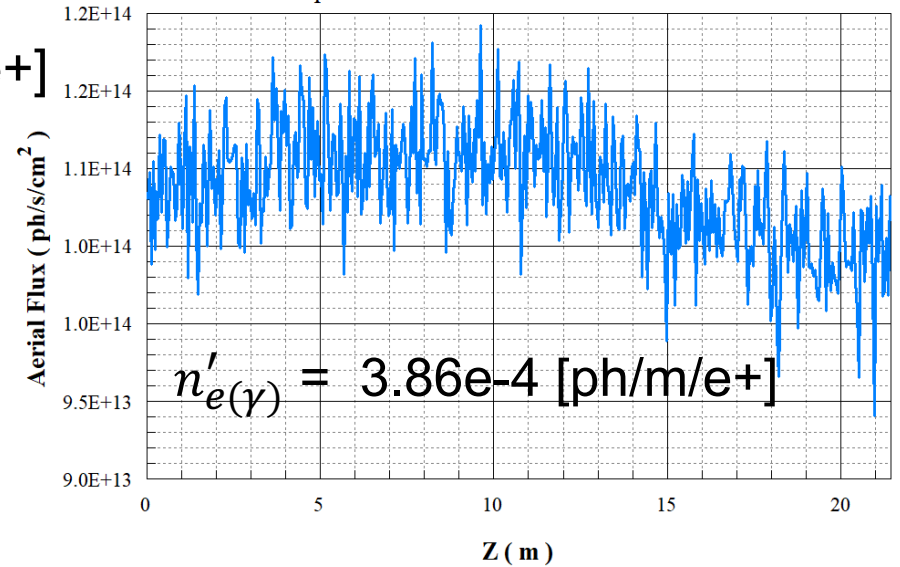
FCC-ee Z: Aerial Photon Flux along 4x 0.3 cm-wide Strips
Center of Dipole Chamber with Absorbers (zoom on 1st Absorber)



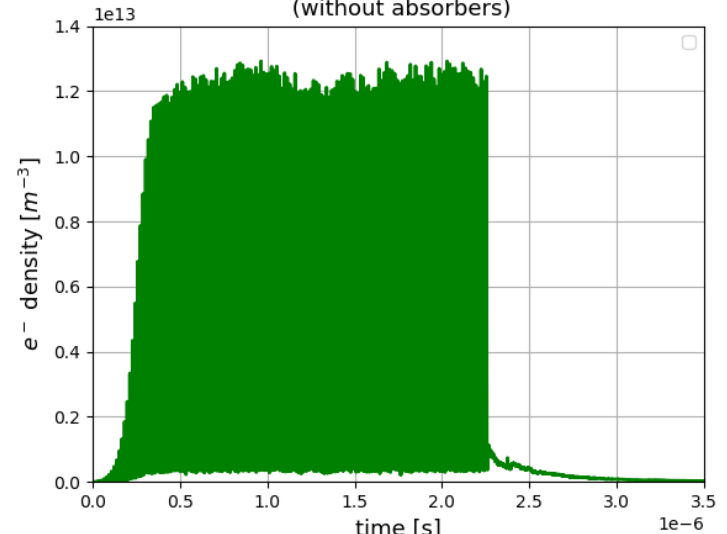
Bunch Space = 15ns, SEY=1.4, $n'_\gamma = 3.51e-5$
(with absorbers)



FCC-ee Z: Aerial Photon Flux along 4x 0.3 cm-wide Strips
Center of Dipole Chamber without Absorbers



Bunch Space = 15ns, SEY=1.4, $n'_\gamma = 3.86e-4$
(without absorbers)



Conclusions

- Effects of SEY and $n'_{e(\gamma)}$ decrease larger than 15ns bunch spacings compared to shorter bunch spacings.
- SEY has a more significant effect on Ecloud center density as compared to $n'_{e(\gamma)}$.
- Electron densities vary up to factor 25 between bunch passings.
- Densities for the longitudinal bunch lengths of 3.5mm and 12mm for different SEY have similar values.
- Initial results for the beam pipes for the arcs with and without absorbers are obtained.
- Tests will be done for the Ecloud SEY model.

Thank you..

Furman- Pivi Model for various SEY values

TABLE I: Main parameters of the model.

	Copper	Stainless Steel
Emitted angular spectrum (Sec. IIC 1)		
α	1	1
Backscattered electrons (Sec. IIIB)		
$P_{1,e}(\infty)$	0.02	0.07
$\hat{P}_{1,e}$	0.496	0.5
\hat{E}_e [eV]	0	0
W [eV]	60.86	100
p	1	1
σ_e [eV]	2	2
e_1	0.26	0.26
e_2	2	2
Rediffused electrons (Sec. IIIC)		
$P_{1,r}(\infty)$	0.2	0.74
E_r [eV]	0.041	40
r	0.104	1
q	0.5	0.4
r_1	0.26	0.26
r_2	2	2
True secondary electrons (Sec. IIID)		
$\hat{\delta}_{ts}$	1.8848	1.22
\hat{E}_{ts} [eV]	276.8	310
s	1.54	1.813
t_1	0.66	0.66
t_2	0.8	0.8
t_3	0.7	0.7
t_4	1	1
Total SEY^a		
\hat{E}_t [eV]	271	292
$\hat{\delta}_t$	2.1	2.05

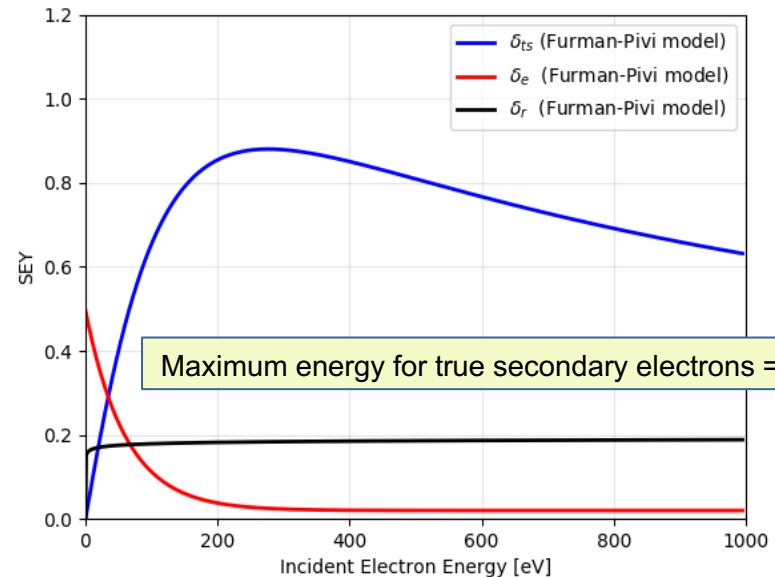
^aNote that $\hat{E}_t \simeq \hat{E}_{ts}$ and $\hat{\delta}_t \simeq \hat{\delta}_{ts} + P_{1,e}(\infty) + P_{1,r}(\infty)$ provided that $\hat{E}_{ts} \gg \hat{E}_e, E_r$.

1.1

0.88

0.02

0.2



^aNote that $\hat{E}_t \simeq \hat{E}_{ts}$ and $\hat{\delta}_t \simeq \hat{\delta}_{ts} + P_{1,e}(\infty) + P_{1,r}(\infty)$ provided that $\hat{E}_{ts} \gg \hat{E}_e, E_r$.

Densities Δt before bunch arrives

