IBS measurements and simulations

Sergey Tomin

DESY TEMF collaboration

01.05.2023

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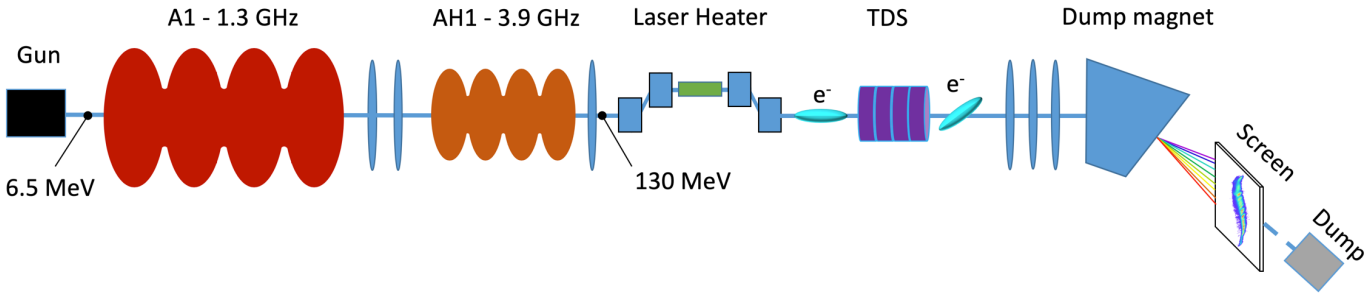
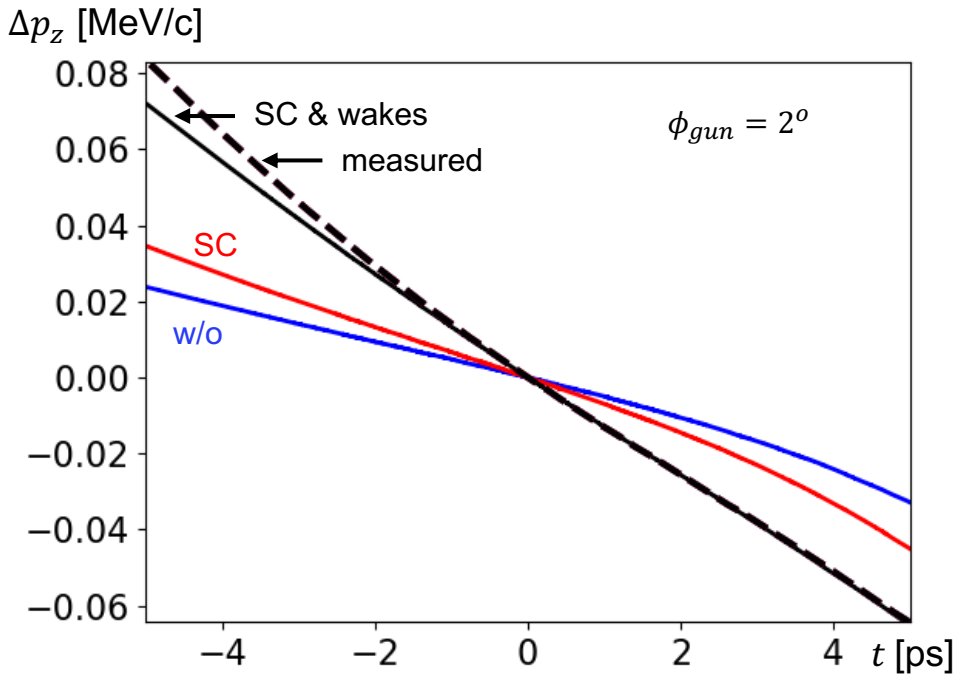
  - **Experimental validation of collective effects modeling at EuXFEL injector**





I. Zagorodnov, S. Tomin, Y.Chen, F. Brinker, Experimental validation of collective effects modeling at injector section of X-ray free-electron laser, Nucl. Instrum. Methods Phys. Res., Sect. A 995 165111, 2021

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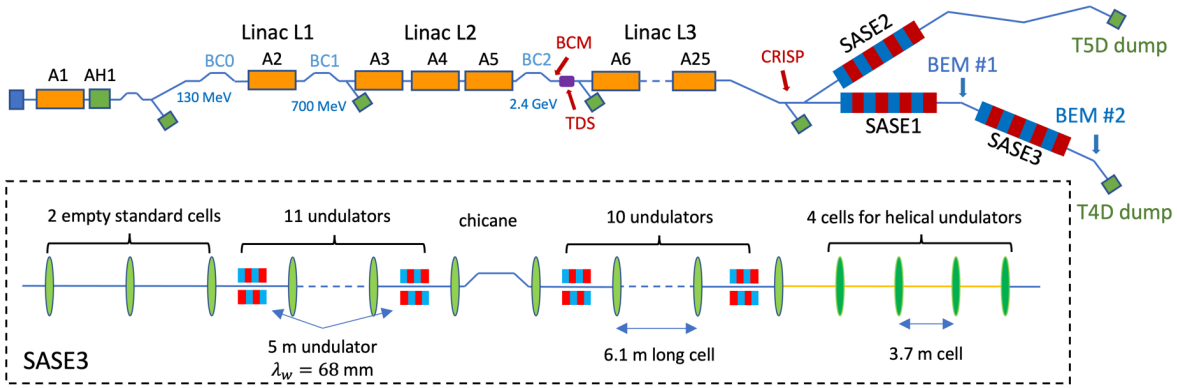
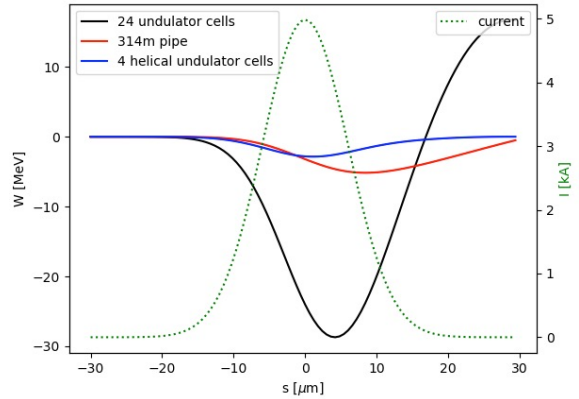
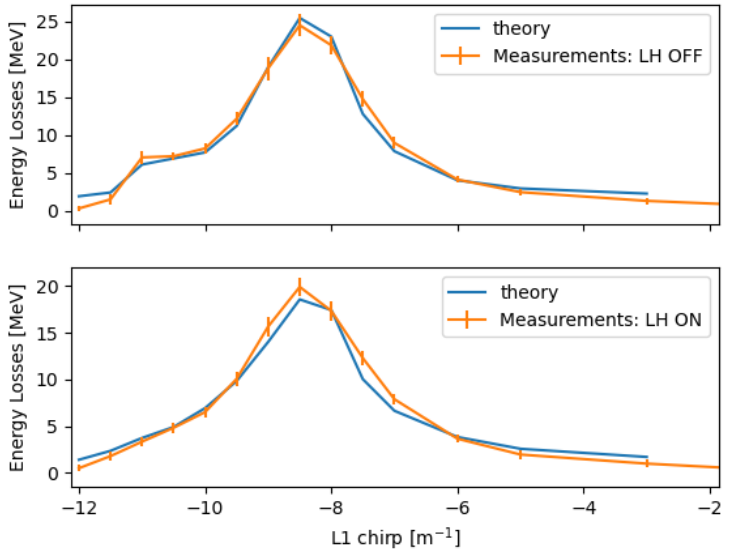
- We began a campaign to validate simulation with experiment:
  - Experimental validation of collective effects modeling at EuXFEL injector
  - **Wakefield energy losses in undulator**







S. Tomin, N. Lockmann, T. Wohlenberg, I. Zagorodnov, Wakefield Energy Losses in the Undulator Section of the European XFEL, IPAC23, TUPL017

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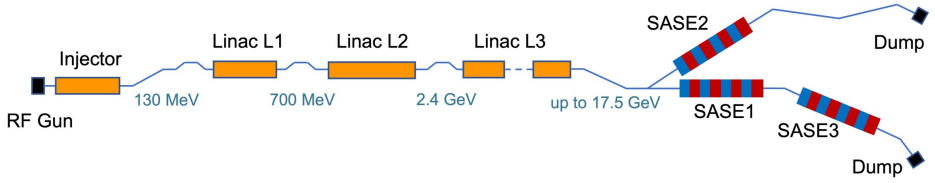
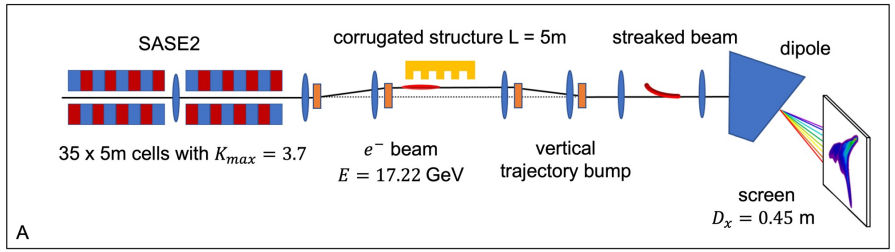
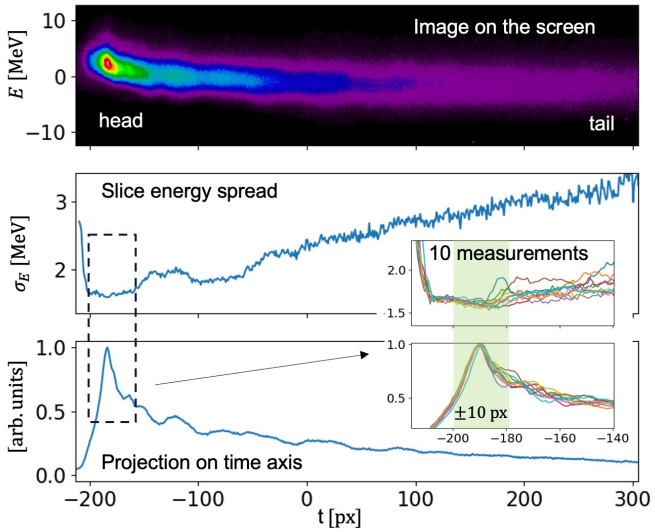
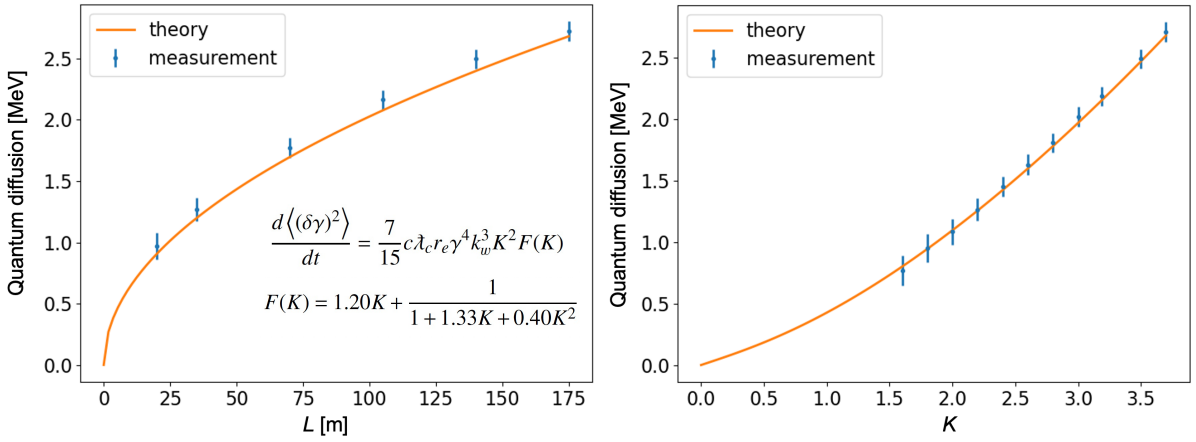
  - Wakefield energy losses in undulator
  - **Quantum diffusion measurements**







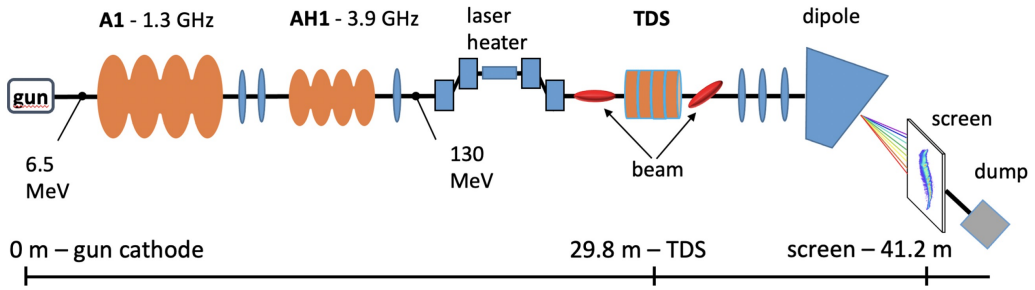
Theory: E.L. Saldin, E.A. Schneidmiller, M.V. Yurkov,

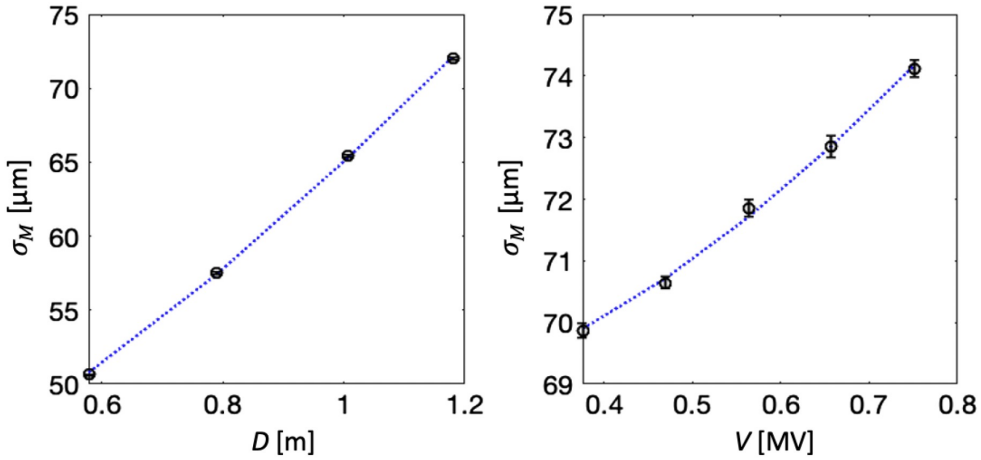


S.Tomin, E.Schneidmiller, W. Decking , First measurement of energy diffusion in an electron beam due to quantum fluctuations in the undulator radiation, Scientific Reports 13, 1605 (2023)

Motivation

- We began a campaign to validate simulation with experiment:
  - Experimental validation of collective effects modeling at EuXFEL injector
  - Wakefield energy losses in undulator
  - Quantum diffusion measurements
  - **Energy spread measurement**



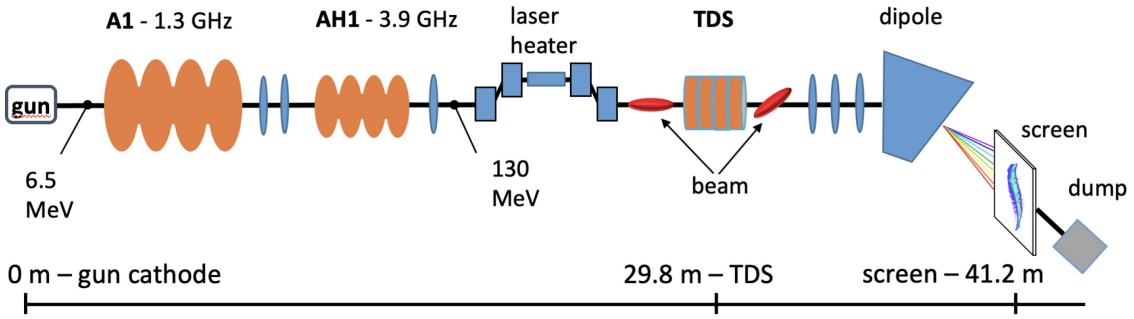


The energy spread for a bunch charge of 250 pC is **5.9 ± 0.1 keV**. This number is approximately 3 times lower then the energy spread of **14.8 ± 0.6 keV** reported by SwissFEL for the bunch charge of 200 pC [1]

S.Tomin et al, Accurate measurement of uncorrelated energy spread in electron beam, Phys. Rev. Accel. Beams 24, 064201 (2021)

1. *E. Prat, P. Dijkstal, E. Ferrari, A. Malyzhenkov, and S. Reiche, High resolution dispersion-based measurement of the electron beam energy spread, Phys. Rev. Accel. Beams 23, 090701 (2020).*

Energy spread measurements: theory



$$\sigma_E^{\mathrm{IBS}} = \sqrt{\frac{2r_e^2 N_b}{\epsilon_n} \int \frac{ds}{\sigma_x \sigma_z}} = 2 \text{ keV}$$

Z. Huang, Intrabeam Scattering in an X-ray FEL Driver, SLAC Report No. SLAC-TN-05-026, 2002.

E. Gjonaj et al, Intrabeam Scattering Effects in the Electron Injector of the European XFEL, FEL2022, WEP14

"The simulations including IBS effects predict a (central slice) SES of roughly **2 keV** for the E-XFEL injector."

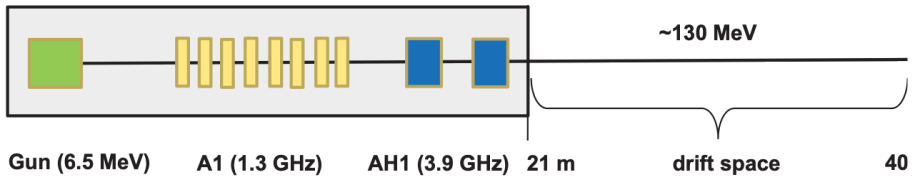
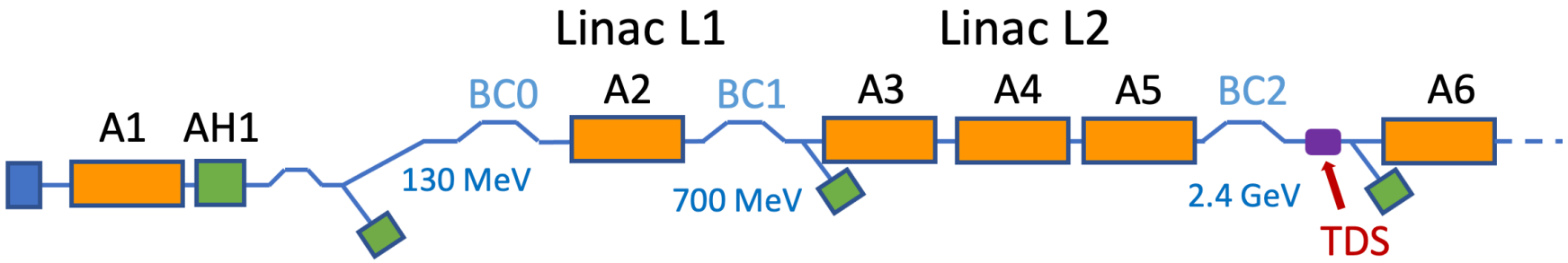


Figure 1: Schematics of the E-XFEL injector beam line.

IBS Discussion: experimental works

- S Di Mitri et al, Experimental evidence of intrabeam scattering in a free-electron laser driver, New J. Phys. 22 (2020) 083053
- E. Prat, P. Dijkstal, E. Ferrari, A. Malyzhenkov, and S. Reiche, High resolution dispersion-based measurement of the electron beam energy spread, Phys. Rev. Accel. Beams 23, 090701 (2020). → 14.8 keV@ 100-430 MeV
- S.Tomin et al, Accurate measurement of uncorrelated energy spread in electron beam, Phys. Rev. Accel. Beams 24, 064201 (2021) → 5.9 keV @130 MeV
- H. Qian, et al, Slice energy spread measurement in the low energy photoinjector, Phys. Rev. Accel. Beams 25, 083401 (2022). 1.65 keV @20 MeV
- E.Prat et al, Energy spread blowup by intrabeam scattering and microbunching at the SwissFEL injector, PRAB 25, 104401 (2022). *"For the standard 200-pC case, we have shown that the energy spread can be improved from up to 14 keV to about 6 keV by reducing the R56 of the two chicanes and further down to about 4 keV by additionally increasing the lattice β function. These 4 keV may be related to remaining IBS,* space-charge, or cathode effects."

IBS measurements in the EuXFEL



- We tried to measure SES in the Injector and after BC2, but due to technical issues we could not succeed
- However we measured SES in the Injector
- The main differences between two measurements in the injector
  - New gun cathode
  - **Reduced gun gradient**
  - **Reduced current of the solenoid**

Stuart Walker

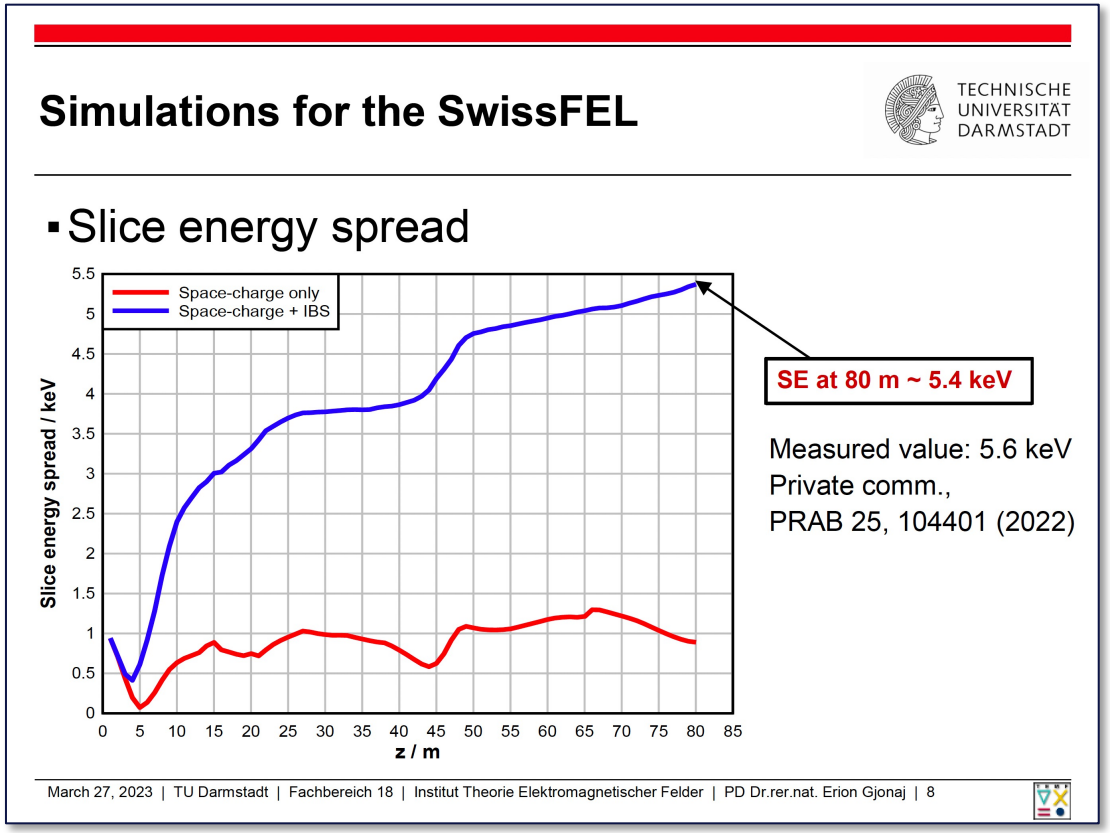
Variable	Feb. 2021	Nov. 2022	Unit
σ_E	5.8(1)	4.3(1)	keV
σ_I	68.0(1)	64.0(8)	μm
σ_B	29.0(6)	28.0(4)	μm
σ_R	28.0(8)	27.0(5)	μm
ε_n	0.38(2)	0.34(9)	mm · mrad

Optics?

HELMHOLTZ GEMEINSCHAFT
DESY

IBS simulations. Outlook

- Erion's simulation results for PSI indicate that our measurements might be explained by IBS
- We need support from Erion for IBS simulations
  - Couple of weeks ago we sent our lattice
- Measurements of SES in injector with different parameters R56?
- Measurements of SES in injector and B2D at the same experimental run



From Erion Gjonaj talk on S2E seminar at DESY, March 27