Report from LEDS’23 workshop

Chris Richard

LEDS2023

Longitudinal Electron beam Dynamics for coherent light Sources

HELMHOLTZ

DESY.

Event: LEDS2023 Longitudinal Electron beam Dynamics for coherent light Sources

3 – 5 October 2023, ENEA (Frascati, Rome)
In-person only. Chairs: S. Di Mitri (Elettra) and F. Nguyen (ENEA)

Organizers: Elettra Sincrotrone Trieste, ENEA

Sponsors: LEAPS, Compact

Aim: Share know-how, provide mutual update and offer solutions to challenges, related to most recent advancements in the generation of high brightness electron beams from photo-injectors for coherent light sources. These include in particular seeded X-ray free-electron lasers and multi-THz superradiant sources.

Contents:
1. Examples of successful applications to EU funds in accelerators for light sources
2. New coherent and cost-effective light sources in the THz and X-ray range
3. Energy spread and intrabeam scattering in high brightness electron photo-injectors
4. Diagnostics for electron beam longitudinal phase space
5. Electron beam longitudinal compression and related collective instabilities

Numbers:
3 days, lunch-to-lunch
39 participants from 16 Institutions and 7 EU Countries + UK & China
22 contributions + 6 round tables

Slide from S. Di Mitri

Outcomes:

Slide from S. Di Mitri

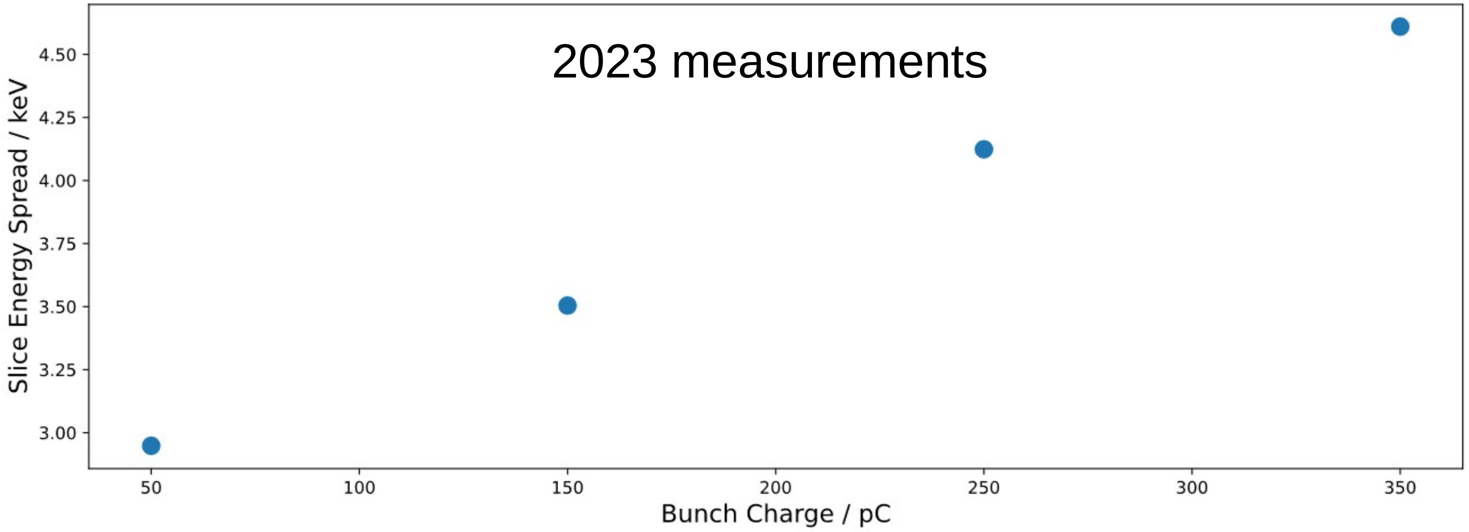
- CompactLight resulted to be a winning action by virtue of wide collaboration effort, shared know-how at state-of-the-art level between all members, production of a conceptual design report with technical specification for new hardware production, involvement of industry on specific items.
- The unprecedented electron beam brightness available nowadays and the need of large degree of full coherence of radiation at higher photon energies moves the attention to previously neglected (and so far negligible) challenges:
  - 1-to-1 particle modelling from cathode emission to MeV energy range including long- and short-range space-charge forces, intrabeam scattering, RF nonlinearities, and geometric wakefields;
  - electron beam modulation and/or RF compression at < 100 MeV energy;
  - magnetic control of time-compression, transverse emittance and beam stability at >100 MeV energy;
  - sub-keV energy resolution at photo-injectors, and sub-fs temporal accuracy at linac end.
- Proposal of a benchmarking study:
  - semi-analytical vs. numerical modelling of an existing photo-injector, inclusive of IBS;
  - self-consistent validation and sharing of the semi-analytical and numerical tool(s);
  - experimental sessions to benchmark the theoretical predictions, with special attention to beam energy spread.

Energy spread measurements at the European XFEL

SES appears to be changing/drifting over past few years

- Between 2021 and 2023 the SES has changed fom 5.9 keV to ~4 keV
- Beamline changes during this time
  - Cathode changed
  - Bunch length 4 ps → 5 ps
- Simulations with IBS predict ~3 keV
- New scripts developed to make SES easier/faster
  - Hopefully we will see more SES studies coming for EuXFEL

Scenario	σ_E / keV	Solenoid / A	Gun Gradient / MV m^{-1}	Gun Phase / °
Feb. 2021 Published Result	5.842	338	56.7	-42.9
Nov. 2022 Measurement 1	4.313	326.6	54.7	-43.1
Nov. 2022 Measurement 2	3.635	336	56.5	-43.6
Nov. 2022 Measurement 3	3.385	335	56.5	-41.6



From S. Walker

SES simulations

Need to accurately simulate the SES is becoming more important for FEL developement

- We need to move away from macro-particles for accurate IBS simulations → need to go towards more particles
- Best algorithm for speed and accuracy depends on the desired number of particles
  - General agreement that it is best to transform to beam frame, calculate forces, update particles, then transform back to lab frame
- For speed, a method is needed to determine which particles are close enough for calculation of collision effects
  - No obvious best way to do this
- No methods (presented here) are applicable at the cathode!

Particles
1k
10k
100k
1M
10M
100M
1G

Obtain electrostatic field:

- O(N²) on a GPU
- Barnes & Hut (GPT)
- Particle-Particle-Particle-Mesh
- Fast multipole method

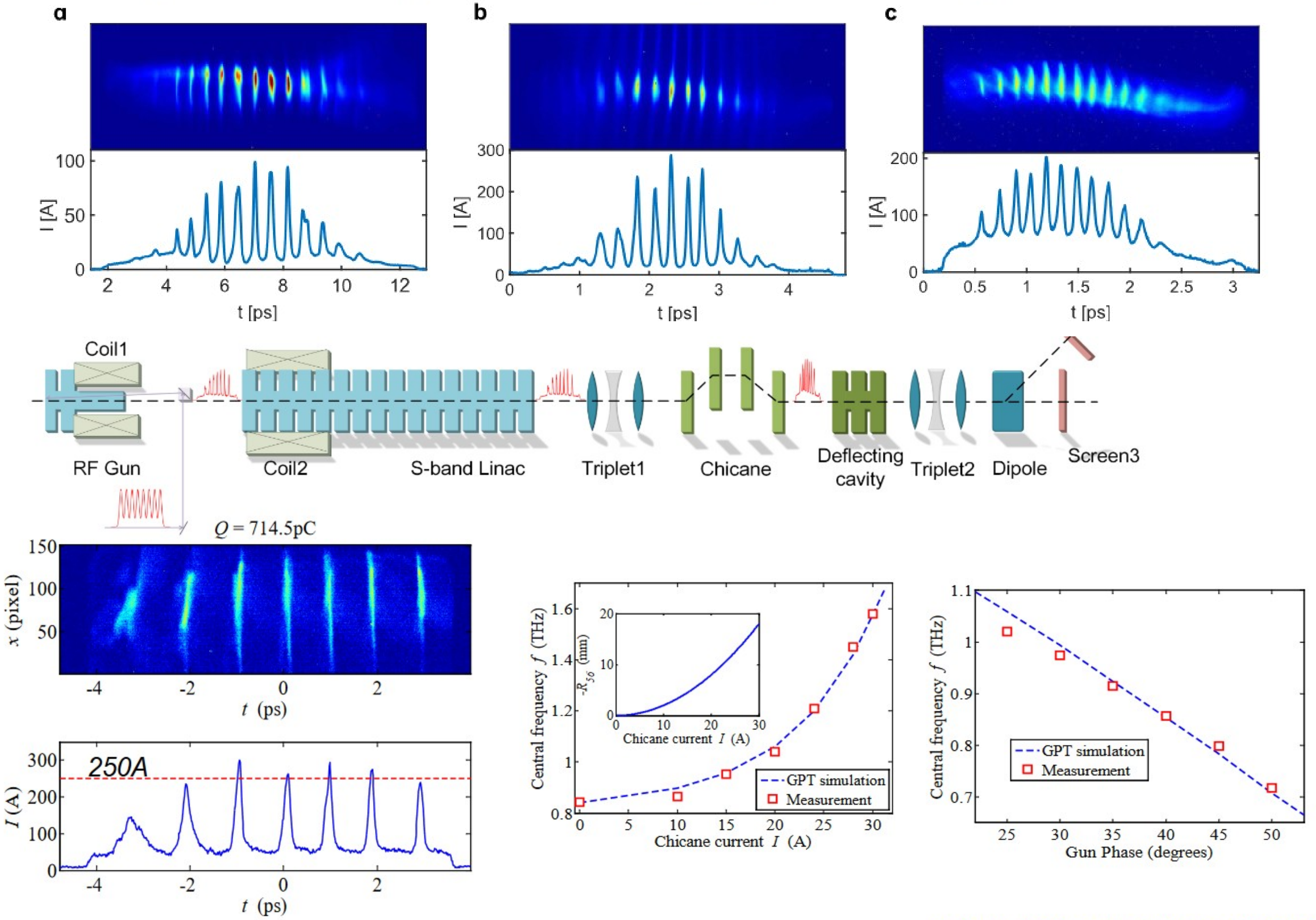
How NOT to simulate stochastic effects

Do NOT naively use macro particles
That is NOT a good idea
Seriously, do NOT do this
It will NOT give correct results

From B. van der Geer

1-10 THz source at Tsinghua University

Developing a tunable THz source via laser modulations



Parameters	Value
Gradient of electron gun	110MV/m
Bunch charge	0-1000pC
Beam energy at gun exit	5MeV
Beam energy at linac exit	42MeV
Projected energy spread	0.2%
Voltage of deflecting cavity	3MV

- General concept: Tune the central frequency by varying the microbunch separation
  - Separation changed by varying laser modulation and compression
- Showed 0.6-2 THz tunability

From L. Yan, Z. Liu

Z Zhang, LX Yan, et al, PRL 116, 184801 (2016)

Thank you

Contact

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