JSPEC - An Open Source Program for IBS and Electron Cooling Simulation

He Zhang , Max Bruker, Yuhong Zhang, Steve Benson
Jefferson Lab, Newport News, VA 23606, USA

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Overview

Jlab Simulation Package for Electron Cooling (JSPEC)

- Being developed and maintained at Jefferson Lab
- Calculates the Intrabeam scattering (IBS) rate and electron cooling rate.
- Simulates the ion beam evolution under the IBS effect and/or electron cooling effect.
- Calculates the instant luminosity during the cooling process.
- Benchmarked with other codes and experimental data.

- Written by C++ for high efficiency.
- Parallelized using OPENMP for shared memory structure.
- Open source, codes and documents are available on Github: https://github.com/JeffersonLab/ElectronCooling
- A Python version is under construction.

Features

Ion beam model

- Bunched (Gaussian distribution)
- Coasting (Gaussian distribution)
- No-Gaussian ion beam model will be finished soon.

Electron beam model

- DC (uniform distribution, Gaussian distribution, hollow)
- Bunched (uniform distribution, Gaussian distribution, hollow)
- Arbitrary distribution

Friction force formulas

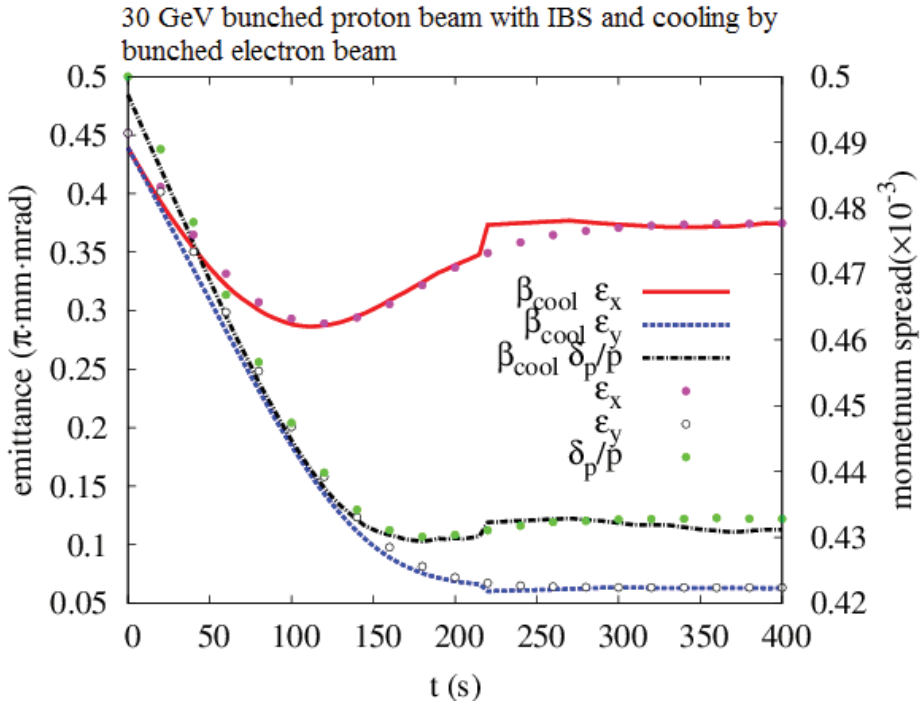
- Non-magnetized force: 1D numerical integration formula, Meshkov asymptotic formula, Derbenev asymptotic formula, 3D numerical integration formula
- Magnetized force: Parkhomchuk formula, Derbenev-Skrinsky-Meshkov formula with numerical integrations, Meshkov asymptotic formula

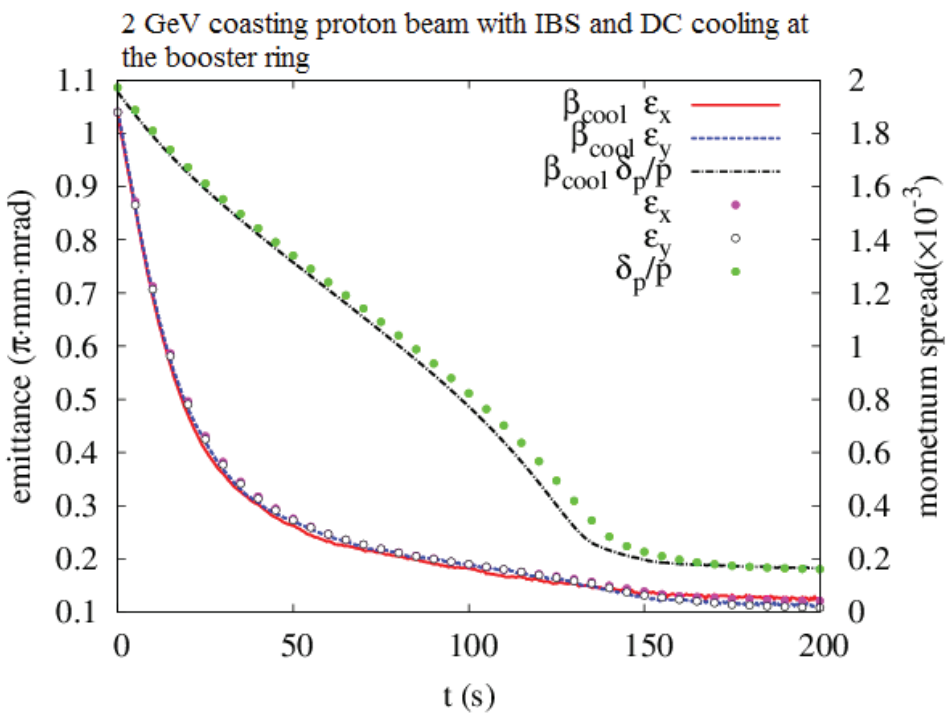
Simulation models

- RMS dynamic model
- Particle model
- Turn-by-turn model

Benchmark

Benchmark with BETACOOL





Benchmark

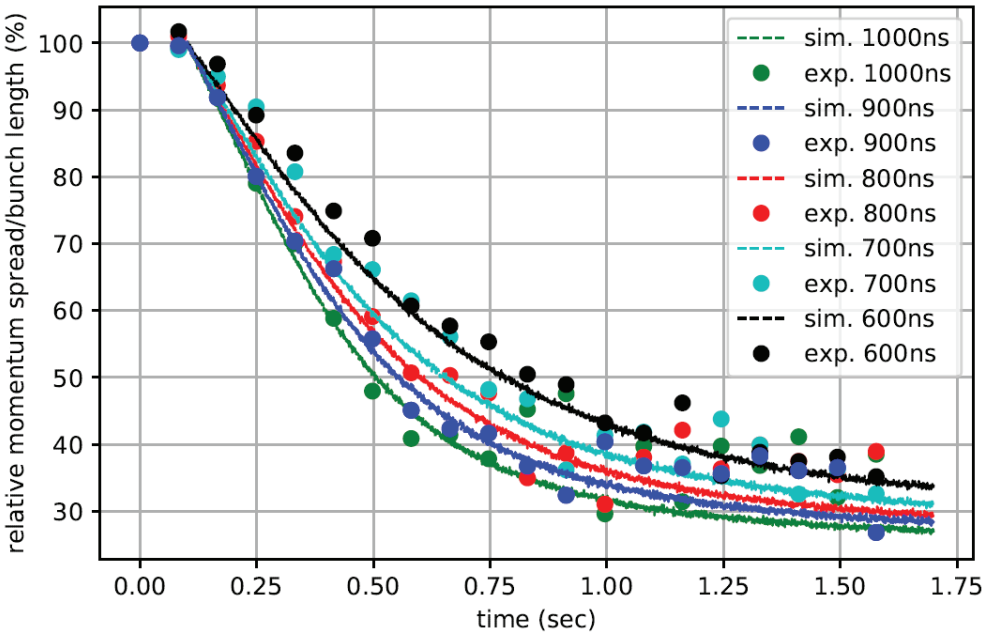
Simulation of the cooling on the Kr beam using pulsed electron beam [1]

TABLE I. Beam and instrumentation parameters.

Ion beam	
Particle type	$^{86}Kr^{25+}$
Beam current	< 0.1 mA
Rest mass	930.5 MeV/nucleon
Kinetic energy	5.0 MeV/nucleon
β	0.103
γ	1.005
Revolution frequency	191.5 kHz
Harmonic number	2
rf voltage	0.6–2 kV
Electron cooler	
Acceleration voltage	2.7 kV
Positive grid voltage	50 V
Negative grid voltage	−551 V
Peak current	30 mA

TABLE IV. Cooling simulation parameters.

Transverse electron beam radius	15 mm
Effective cooler length	3.4 m
Magnetic field	0.1 T
Average β_x/β_y in the cooler	10 m / 17 m
Peak electron current (uniform bunch shape)	30 mA
Transverse electron temperature	200 meV
Longitudinal electron temperature	6 meV
RMS normalized transverse emittance	0.6 mm mrad
RMS long. ion bunch size σ_z	10.5 m
RMS long. ion momentum deviation $\sigma_{p_z/p}$	7×10^{-4}



[1] Demonstration of electron cooling using a pulsed beam from an electrostatic electron cooler, M. Bruker, S. Benson, A. Hutton, et. al., PRAB 24, 012801 (2021)

How to use JSPEC

- JSPEC has been tested in Windows and Linux (Ubuntu 18.04) environments.
- Run JSPEC in command line: > jspec.exe *input_file_name*
- Example input file

```
section_ion #define the ion beam
        charge_number = 1
        mass = 938.272
        kinetic_energy = 3e4
        norm_emit_x = 0.4515633419e-6
        norm_emit_y = 0.4515633419e-6
        momentum_spread = 8e-4
        rms_bunch_length = 2.5e-2
        particle_number = 6.56E9
section_ring #define the ring
        lattice = lattice_from_MADX.tfs
section_ibs #define the arguments for IBS calculation
        model = martini
        nu = 200
        nv = 200
        nz = 40
        log_c = 39.9/2
        coupling = 0
section_cooler
        length = 30
        section_number = 2
        magnetic_field = 1
        bet_x = 100
        bet_y = 100
        disp_x = 0.5
        disp_y = 0
section_scratch
        m = 938.272
        ke = 3e4
        gamma_ion = ke/m + 1
```

```
section_e_beam
        gamma = gamma_ion
        tmp_tr = 0.5
        tmp_l = 0.1
        shape = bunched_gaussian
        sigma_x = 0.0012
        sigma_y = 0.0012
        sigma_z = 0.025
        e_number = 1.25E10
section_ecool
        sample_number = 10000
        force_formula = PARKHOMCHUK

section_simulation
        ibs = true
        e_cool = true
        time = 30
        step_number = 200
        output_file = simulation_rms_bunched_both.txt
        model = rms
section_run
        create_ion_beam
        create_ring
        create_e_beam
        create_cooler
        run_simulation
```

Summary

- JSPEC simulates IBS effect and/or electron cooling process.
- Open source: https://github.com/JeffersonLab/ElectronCooling
- Benchmarked with other codes and experimental data.
- Features under construction:
  - IBS for non-Gaussian beam
  - Python wrapper


谢谢
THANK
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