Simulation of beam-gas scattering in LHC using SixTrack

Work in progress

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Thanks to: T. Weiler, F. Schmidt, A. Rossi

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- Structure
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Motivation

- Complement collimation studies
- Understand significance of beam gas interactions in LHC
- Provide beam-gas simulations in multiturn tracking code
- Provide input for particle shower studies in the experiments
- Beam lifetime estimate

Tracking protons

- SixTrack used to track protons (before and) after interaction
- All protons undergo a collision within the first turn of the simulation (i.e. scattering probability normalized to 1)
- Off-momentum acceptance is a few percent (an expanded Hamiltonian is used in SixTrack [1])
- Untrackable particles are written directly to output with coordinates and energy after interaction
- Detailed aperture files are provided by the collimation team

Generating collisions

- DPMJET generates input file for SixTrack
- Each event is a proton at "simulation energy" in collision with a hydrogen atom at rest.
- Other code could be used, flexible input format

Tracking residues in the LSS

Various options: FLUKA, GEANT4, MARS, BDSIM..

Output will be a long list of particle types, coordinates, scattering origin and other relevant information

Output formats will be a standard text file (next slide) and a root binary format (ntuple)

Tracking residues in the LSS

```
# 1=s_origin 2=turn 3=s 4=x 5=xp 6=y 7=yp 8=E 9=impactType 10=particletype
# [m] [] [m] [mm] [mrad] [mm] [mrad] [MeV] [] []
# impactType:
# 1: still in beampipe (non-trackable)
# 2: hit an aperture
# 3: hit a collimator
# particletype: as defined in dpmjet
9680.499999999771 1 9680.499999999771 -8.409058655356001E-02 0.0270931459401 4.797030333624350E-02 -0.106775049039 2296100.29278 1 2212
9680.499999999771 1 9680.499999999771 -8.409058655356001E-02 -0.200146309694 4.797030333624350E-02 0.18547731184 2317112.96681 1 -211
9680.499999999771 1 9680.499999999771 -8.409058655356001E-02 3.3881237016 4.797030333624350E-02 -3.46153283796 43201.9554433 1 211
9680.499999999771 1 9680.499999999771 -8.409058655356001E-02 -4.37551441056 4.797030333624350E-02 -65.6684463234 9616.01251896 1 211
9680.499999999771 1 9680.499999999771 -8.409058655356001E-02 -138.799386566 4.797030333624350E-02 -30.0607293789 3823.10668982 1 -211
9680.499999999771 1 9680.499999999771 -8.409058655356001E-02 75.6997821382 4.797030333624350E-02 6.15984089525 6955.65305229 1 2212
9680.499999999771 1 9680.499999999771 -8.409058655356001E-02 391.583207872 4.797030333624350E-02 276.734233873 1125.93958269 1 -211
9680.499999999771 1 9680.499999999771 -8.409058655356001E-02 6.68296830663 4.797030333624350E-02 14.2734460162 20237.3268118 1 321
1=s_origin 2=turn 3=s 4=x 5=xp 6=y 7=yp 8=E 9=impactType 10=particletype
9680.499999999771 1 9680.499999999771 -8.409058655356001E-02 207.637492075 4.797030333624350E-02 -19.4490093418 5470.44448704 1 111
9680.499999999771 1 9680.499999999771 -8.409058655356001E-02 -9.14390773262 4.797030333624350E-02 18.576179843 15977.5226961 1 -211
9680.499999999771 1 9680.499999999771 -8.409058655356001E-02 3.29731230161 4.797030333624350E-02 -1.20338436413 42502.0854089 1 111
9680.499999999771 1 9680.499999999771 -8.409058655356001E-02 -1.02750950306 4.797030333624350E-02 1.70675684079 60144.6723792 1 22
9680.499999999771 1 9680.499999999771 -8.409058655356001E-02 7.85394277258 4.797030333624350E-02 1.13234818352 62909.1894856 1 22
9680.499999999771 1 9680.499999999771 -8.409058655356001E-02 31.8163958954 4.797030333624350E-02 -54.2460885496 5332.39318114 1 211
9680.499999999771 1 9680.499999999771 -8.409058655356001E-02 -126.247298274 4.797030333624350E-02 93.1186212289 2369.10963514 1 111
9680.499999999771 1 9680.499999999771 -8.409058655356001E-02 -100.361221641 4.797030333624350E-02 69.9767230038 793.536212493 1 111
9680.499999999771 1 9680.499999999771 -8.409058655356001E-02 18.7532703273 4.797030333624350E-02 -118.926128363 1437.50845754 1 111
9680.499999999771 1 9680.499999999771 -8.409058655356001E-02 -200.635237381 4.797030333624350E-02 -88.8702609737 586.151583899 1 111
9680.499999999771 1 9680.499999999771 -8.409058655356001E-02 4.56060669272 4.797030333624350E-02 -0.156290537065 42662.154433 1 211
9680.499999999771 1 9680.499999999771 -8.409058655356001E-02 -0.795788078673 4.797030333624350E-02 8.0807372978 44223.0646088 1 -321
```

More information needed?

Simulation with constant pressure

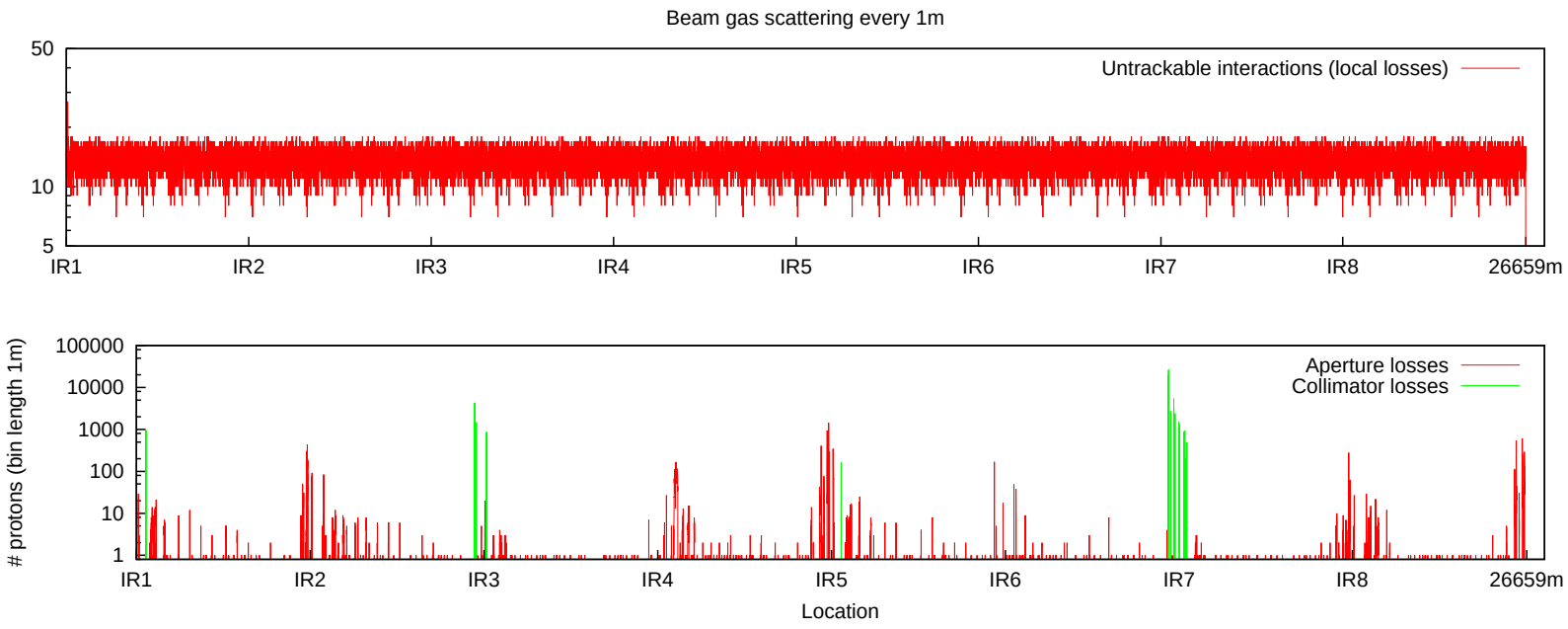
- 500 000 protons
- 300 turns
- 7 TeV beam

Simulation with constant pressure

- 500 000 protons
- 300 turns
- 7 TeV beam
- Make use of lxbatch
- This job used ∼500 hours of computing time
- Splits into several jobs => ∼10 hours to finish
- Approximately 5-10 TB of raw data

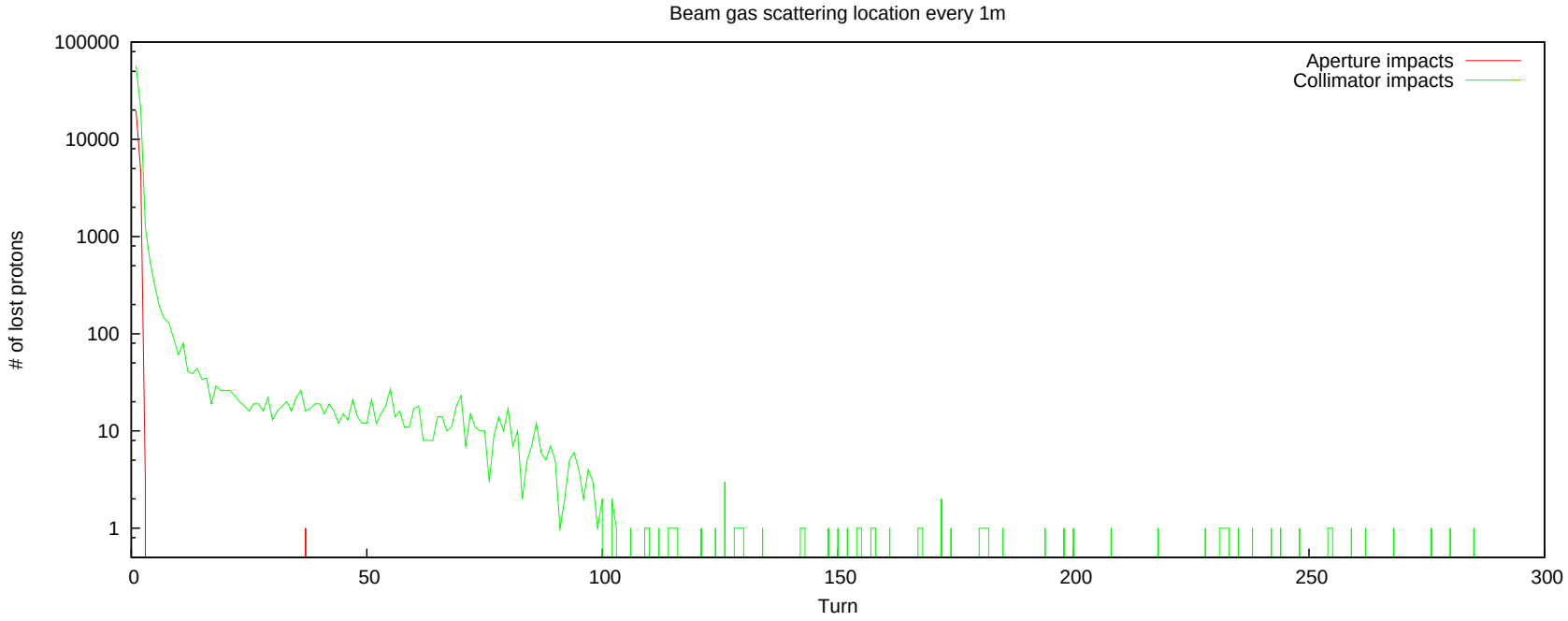
Simulation with constant pressure

Loss event counting



Simulation with constant pressure

Counting by which turn loss occurs



Adding pressure profile

- Pressure profiles for IR1/5 and IR2/8 are provided by A. Rossi
- Integrated pressure for a given bin length calculated
- A maximum of about 30 000 scattering locations and 800 different scattering probabilities (limitations in sixtrack)

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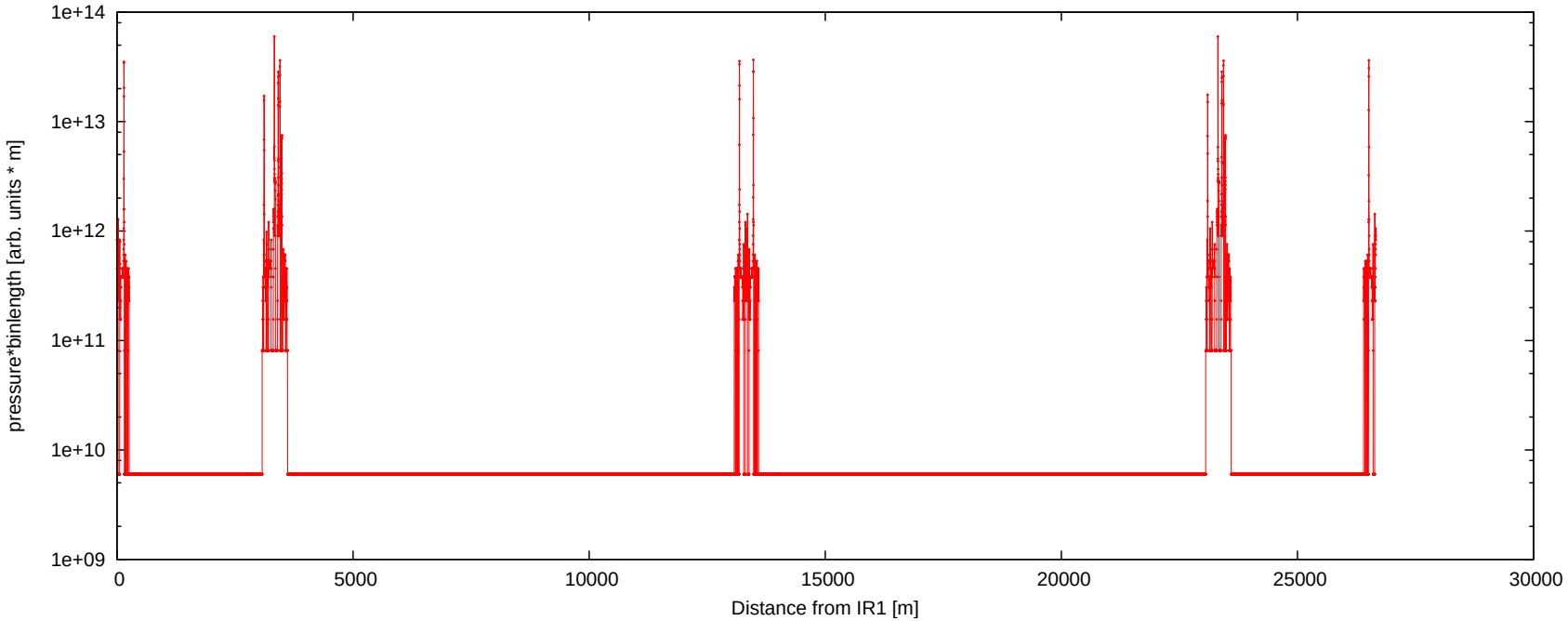

Action items

- Provide clean input files usable for simulations of particle showers ✔
- Include pressure profile ✔
- Calculate beam lifetime
- Simulate injection energy for benchmark comparison
- Check what is included in dpmjet, compare with other event generators (fluka, g4)
- Compare with other beam gas simulations for LHC (N. Mokhov, M. Mauri...)

K. Heinemann, G. Ripken, and F. Schmidt.
Construction of nonlinear symplectic six-dimensional thin-lens maps by exponentiation.
Technical Report DESY 95-189, October 1995.