Dark Current Transport at FLASH

Start-to-end tracking simulation

- analysis of beam and dark current transport
- full 3D aperture model

Dark current losses

- identification of hot spots
- cleaning efficiency of gun and BC2 collimators
- influence of new gun layout

Simulation Steps

Astra simulation of FLASH linac (gun—dump)

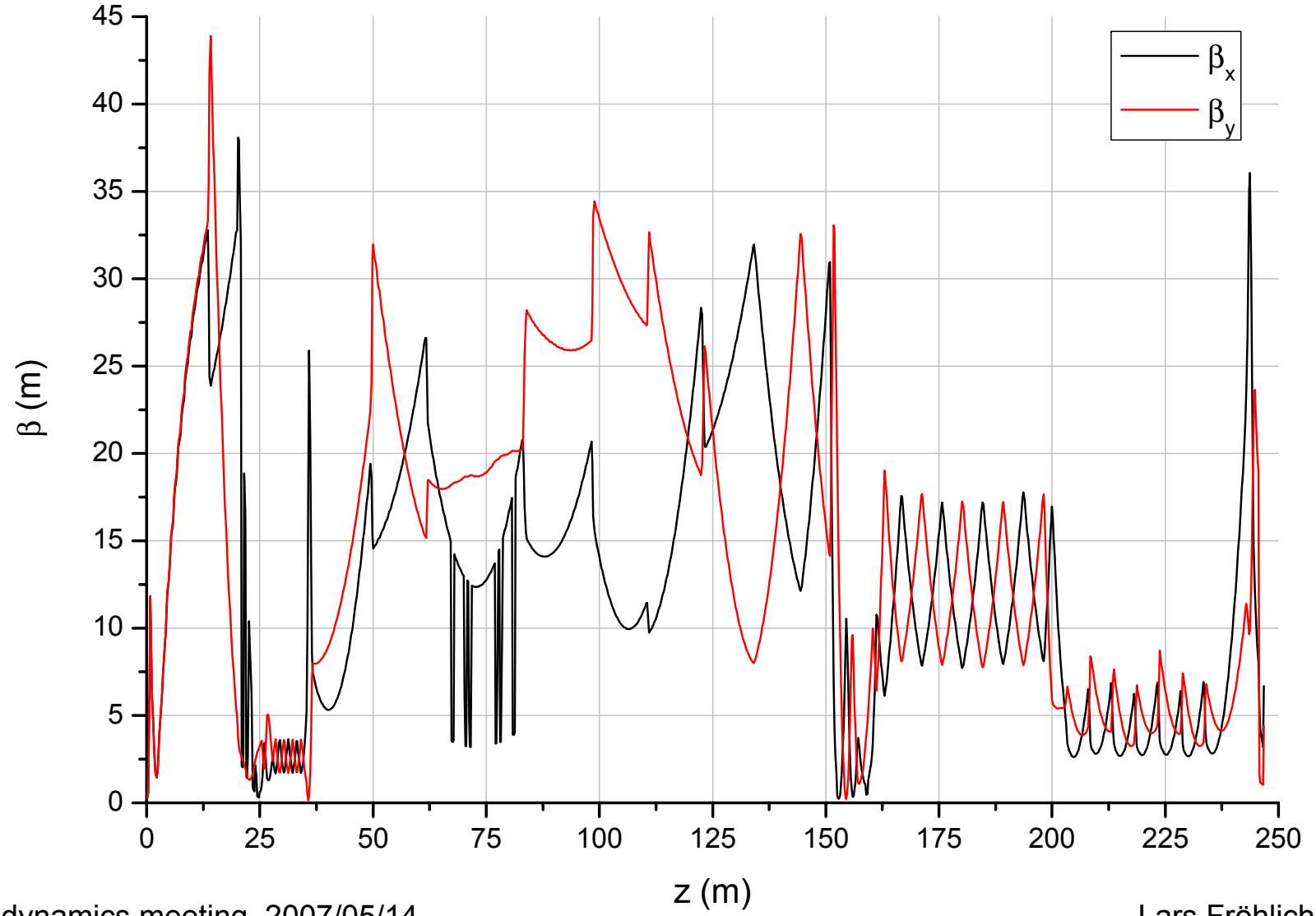
- space charge up to BC2 entrance
- no apertures
- 2500 phase space dumps (one each 10 cm, ~30 GB)
- runtime: ~2 h (44 processors, 400 000 particles)

Aperture check with ApertureLib toolkit

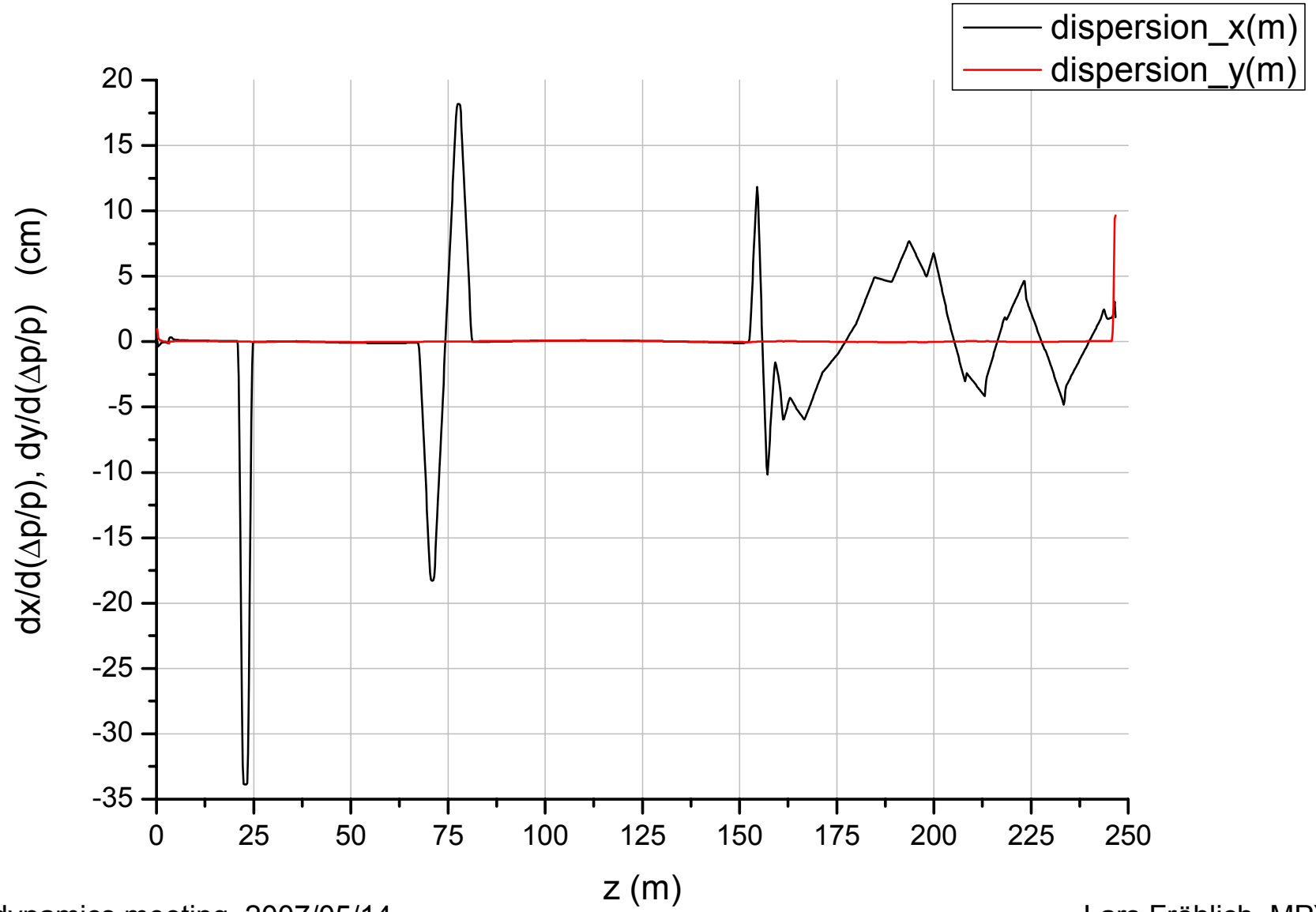
- full 3D model of the accelerator aperture in cartesian coordinates
- outputs: phase space at any position, discarded particles, Twiss parameters, ...
- runtime: ~14 min

1: Machine Model

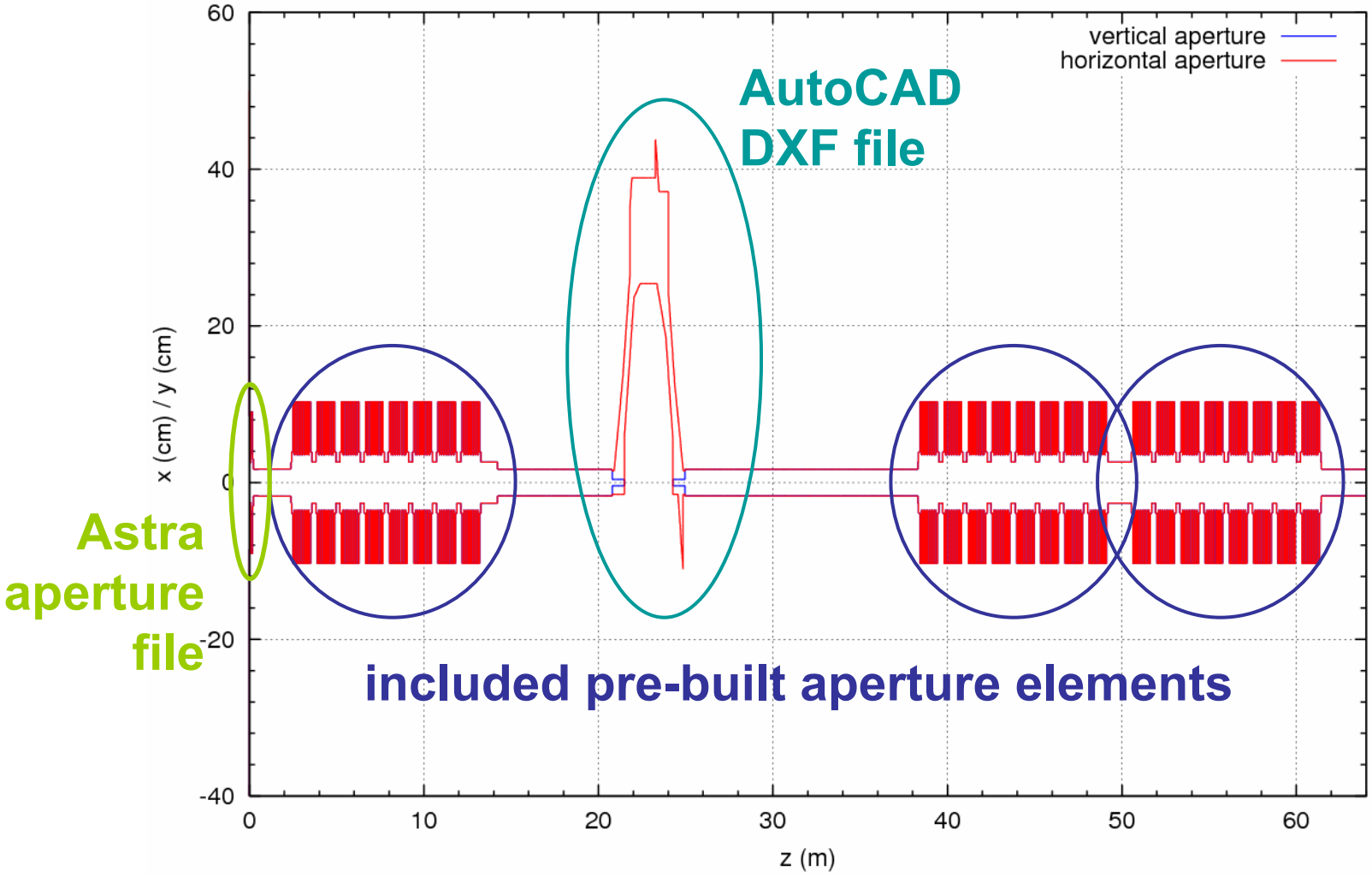
Design Optics



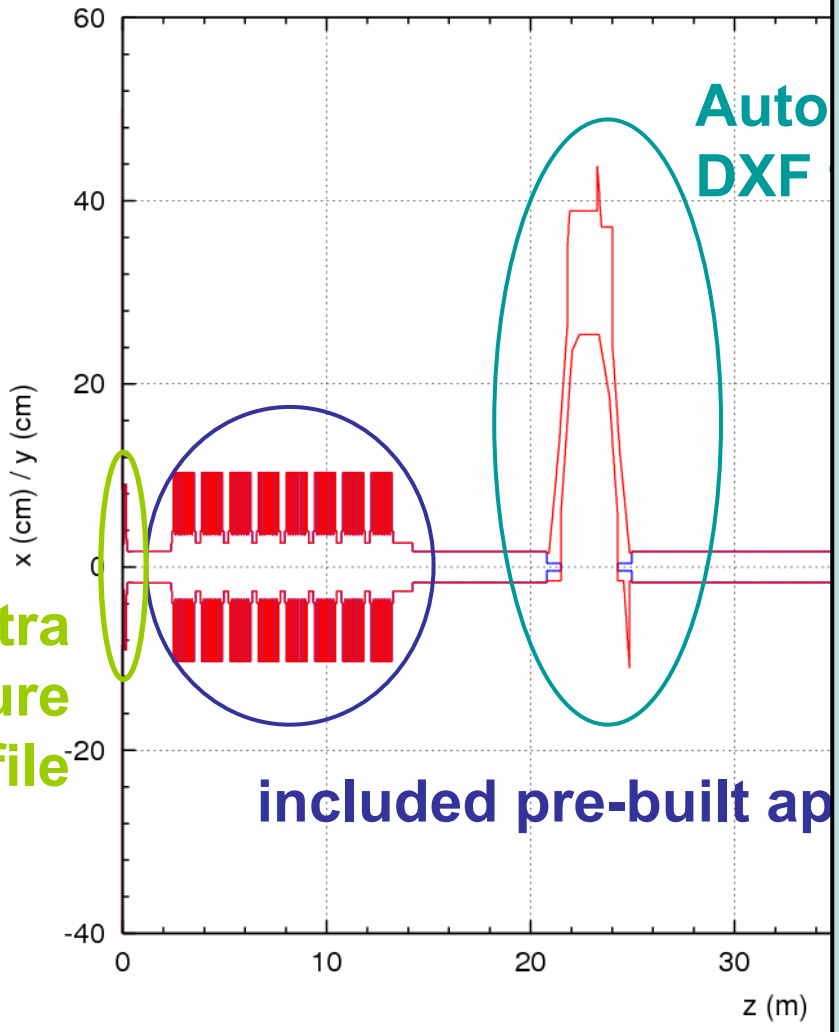
“Dispersion”


dispersion_x(m)
dispersion_y(m)
dx/d(Δp/p), dy/d(Δp/p) (cm)
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
0
25
50
75
100
125
150
175
200
225
250
z (m)

Aperture Model (1)

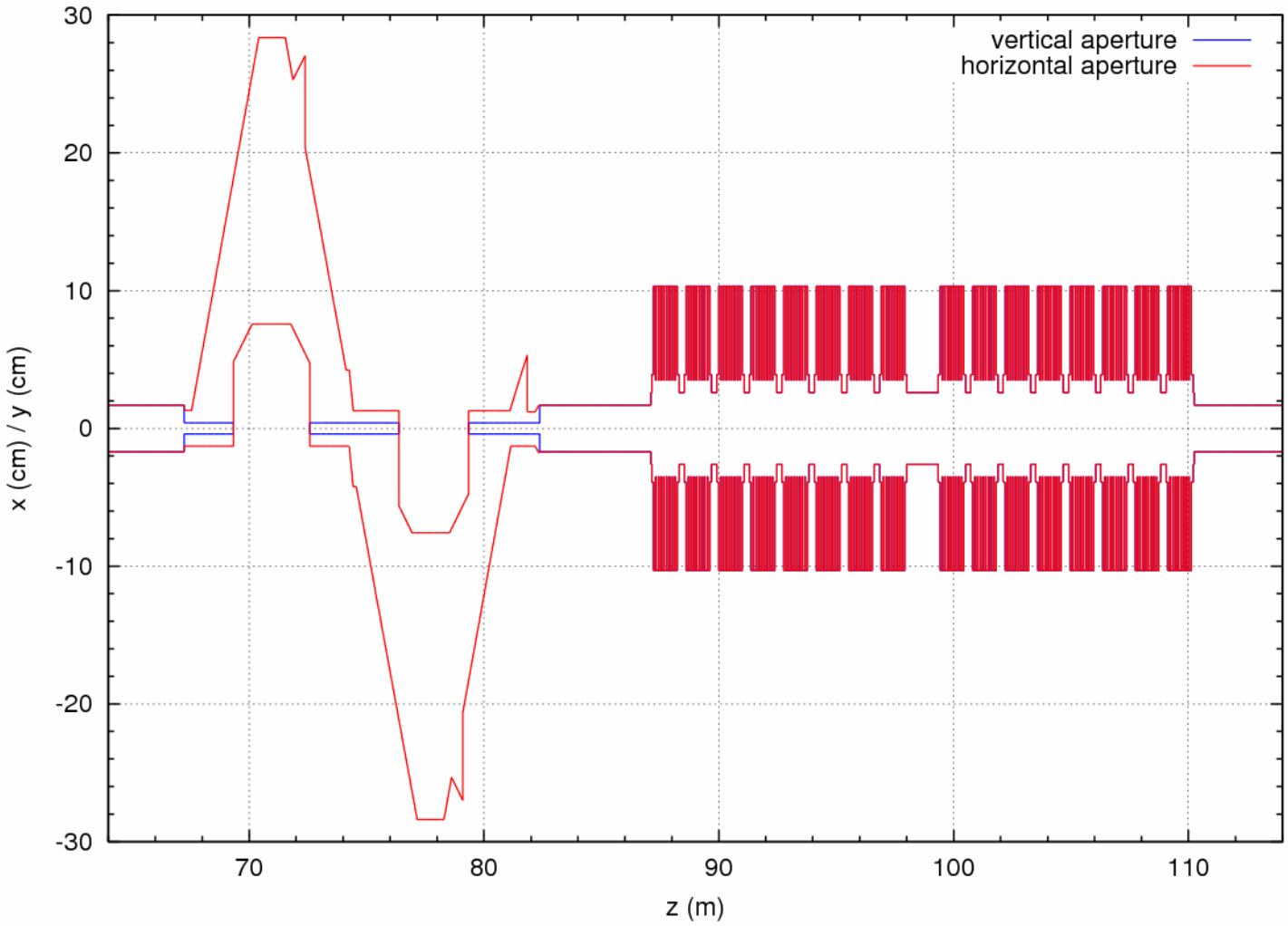


Aperture Model (1)

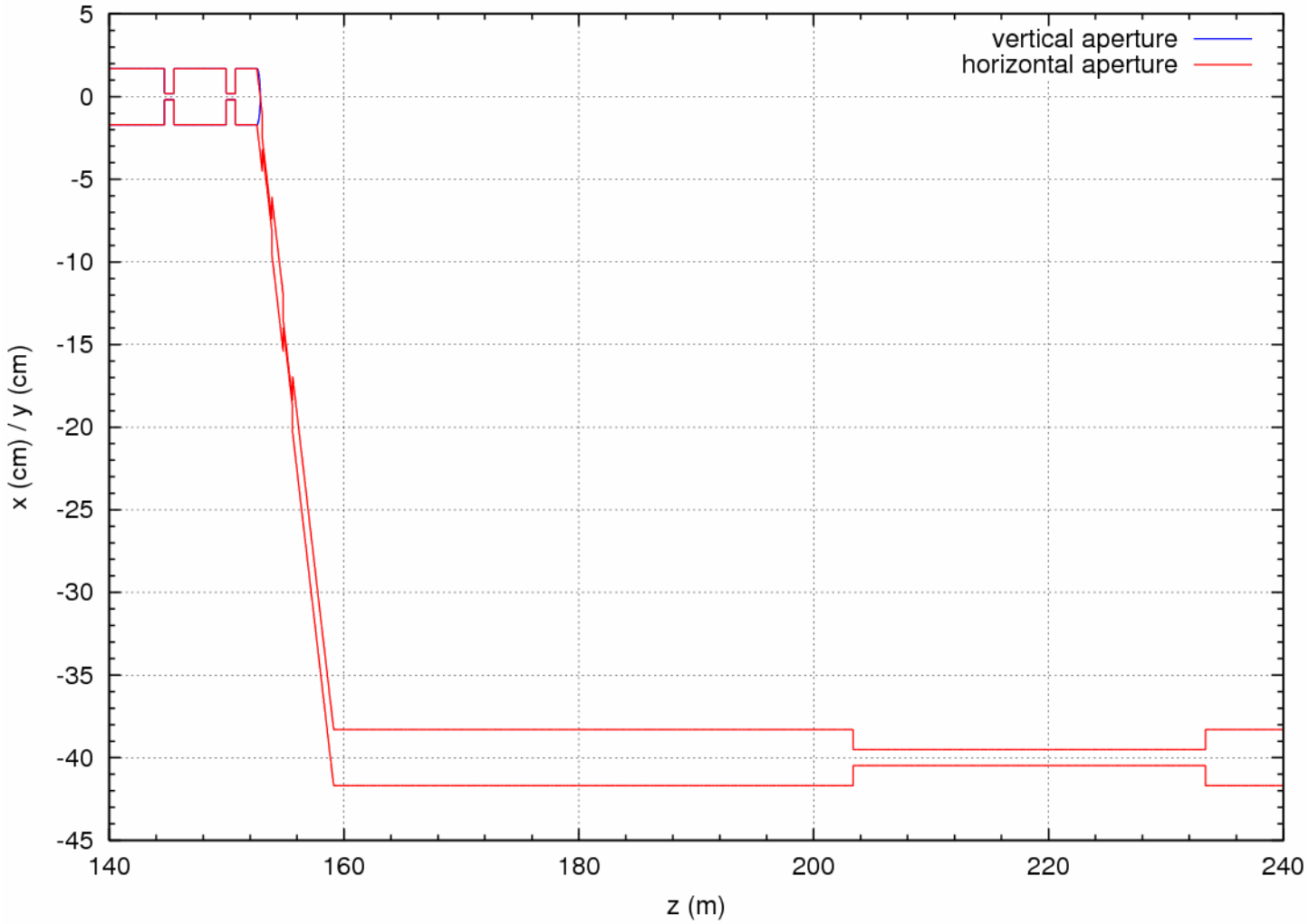



```
- <aperture-list>
  - <radial z="0" name="RF gun">
      <filename>rfgun_radial.asc</filename>
    </radial>
  - <circle z="0.51" name="drift tube">
      <r>0.0175</r>
    </circle>
  - <circle z="1.273" name="gun collimator">
      <r>0.004</r>
    </circle>
  - <circle z="1.277" name="drift tube">
      <r>0.0175</r>
    </circle>
  - <include z="2.3754" name="ACC1">
      <filename>TTF_module.xml</filename>
    </include>
  - <circle z="14.220" name="beampipe behind valve 13ACC1">
      <r>0.017</r>
    </circle>
  + <!---->
  - <and z="20.791">
    - <aperture-list>
      - <dxf z="0" name="BC2 vacuum chamber">
          <filename>BC2.DXF</filename>
          <origin_rotation>180</origin_rotation>
          <ceiling>0.004</ceiling>
          <floor>-0.004</floor>
        </dxf>
      </aperture-list>
    - <aperture-list>
        <null z="0"/>
      - <rectangle z="1.849">
          <x1>-1</x1>
          <x2>0.324</x2>
          <!-- 0.389 is out -->
          <y1>-1</y1>
          <y2>1</y2>
        </rectangle>
        <null z="2.202"/>
      </aperture-list>
    </and>
```

Aperture Model (2)



Aperture Model (3)



2: Dark Current

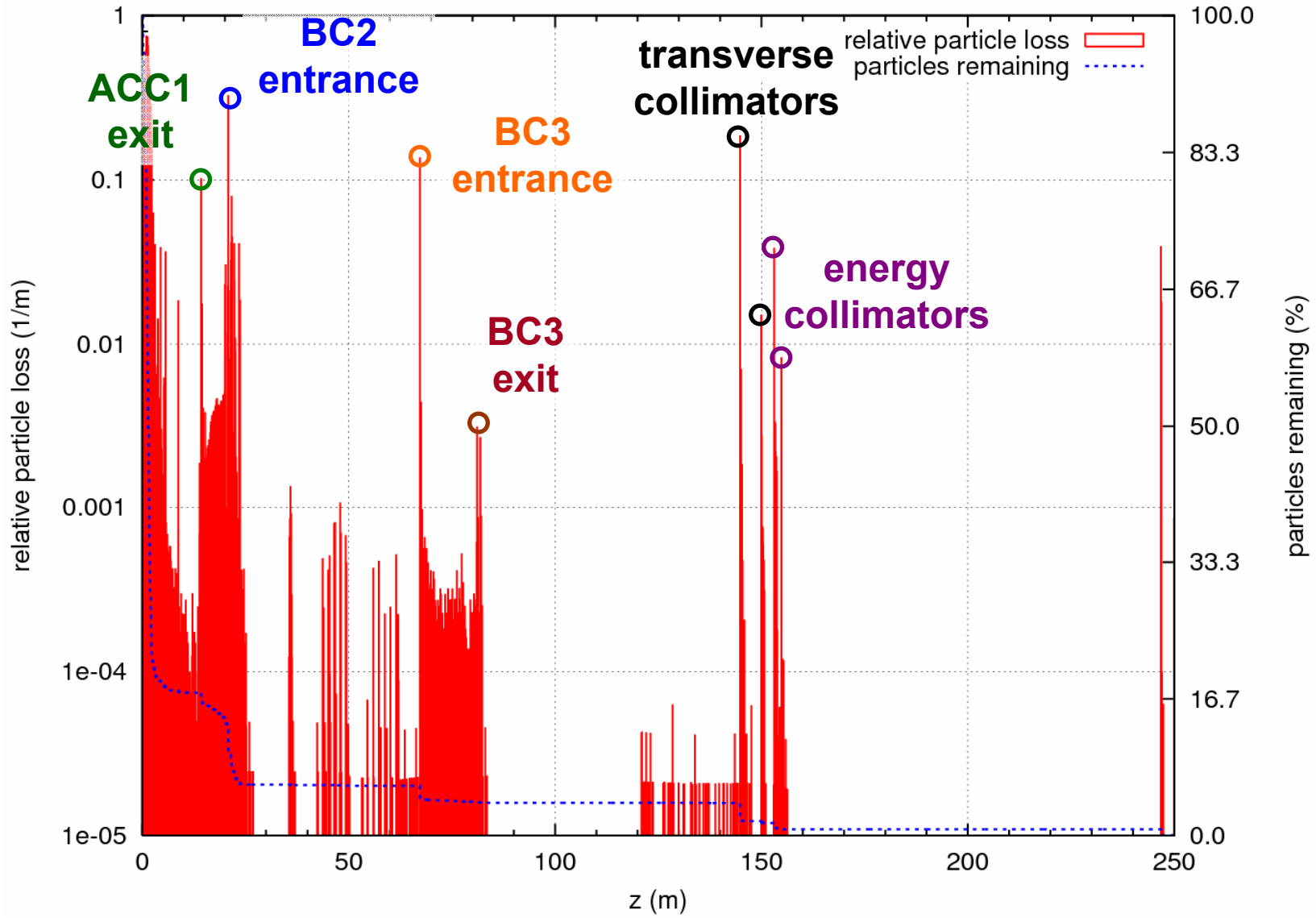
Dark Current Simulation

Dark current emission:

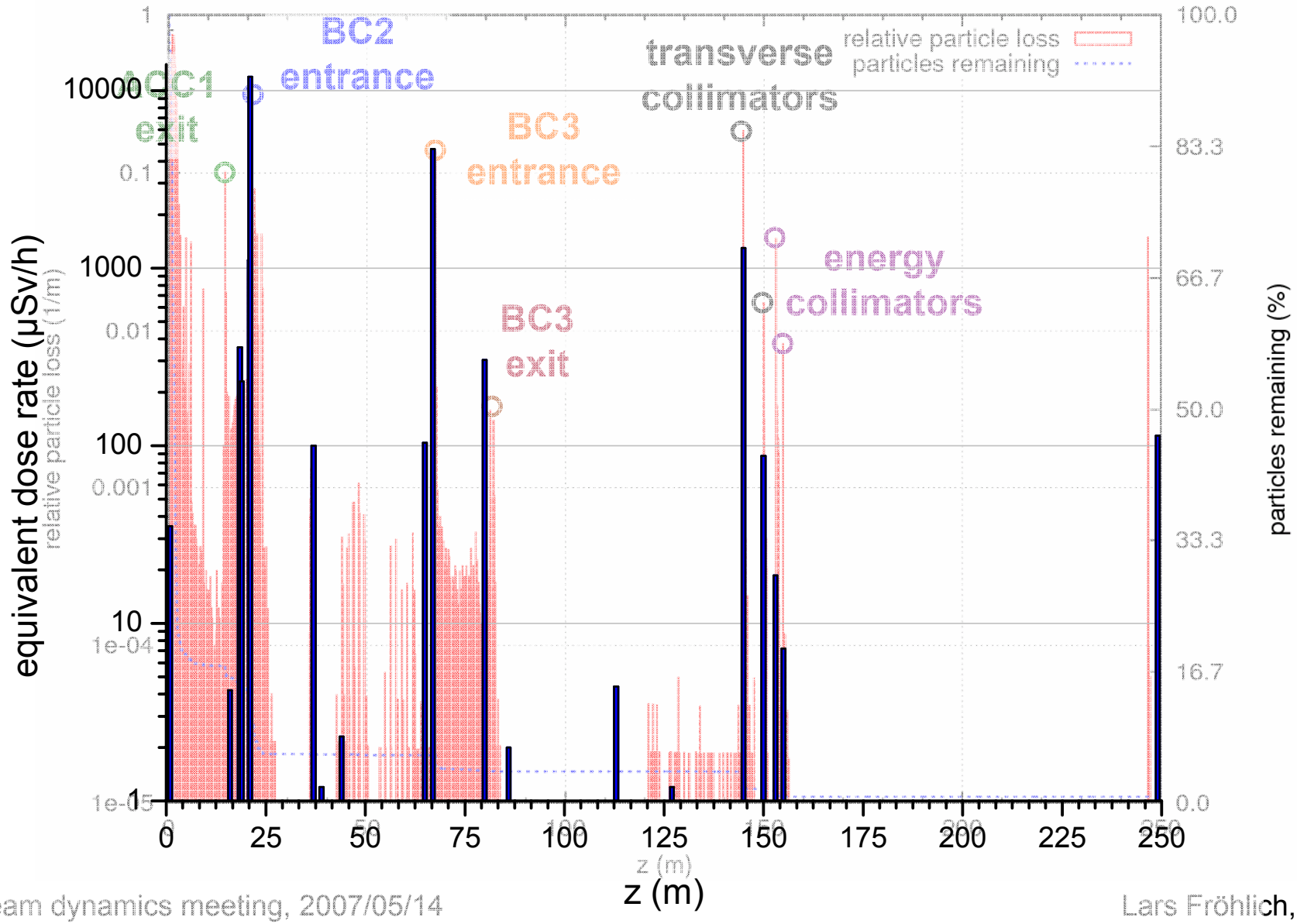
- Simple field emission model
- Current: Gaussian around RF gun phase 0° with σ=16°
- Homogeneous emission from cathode surface (Ø 5 mm)
- Current exiting the gun 200–300 µA

- no simulation of collective effects
  (space charge, CSR, ... negligible)

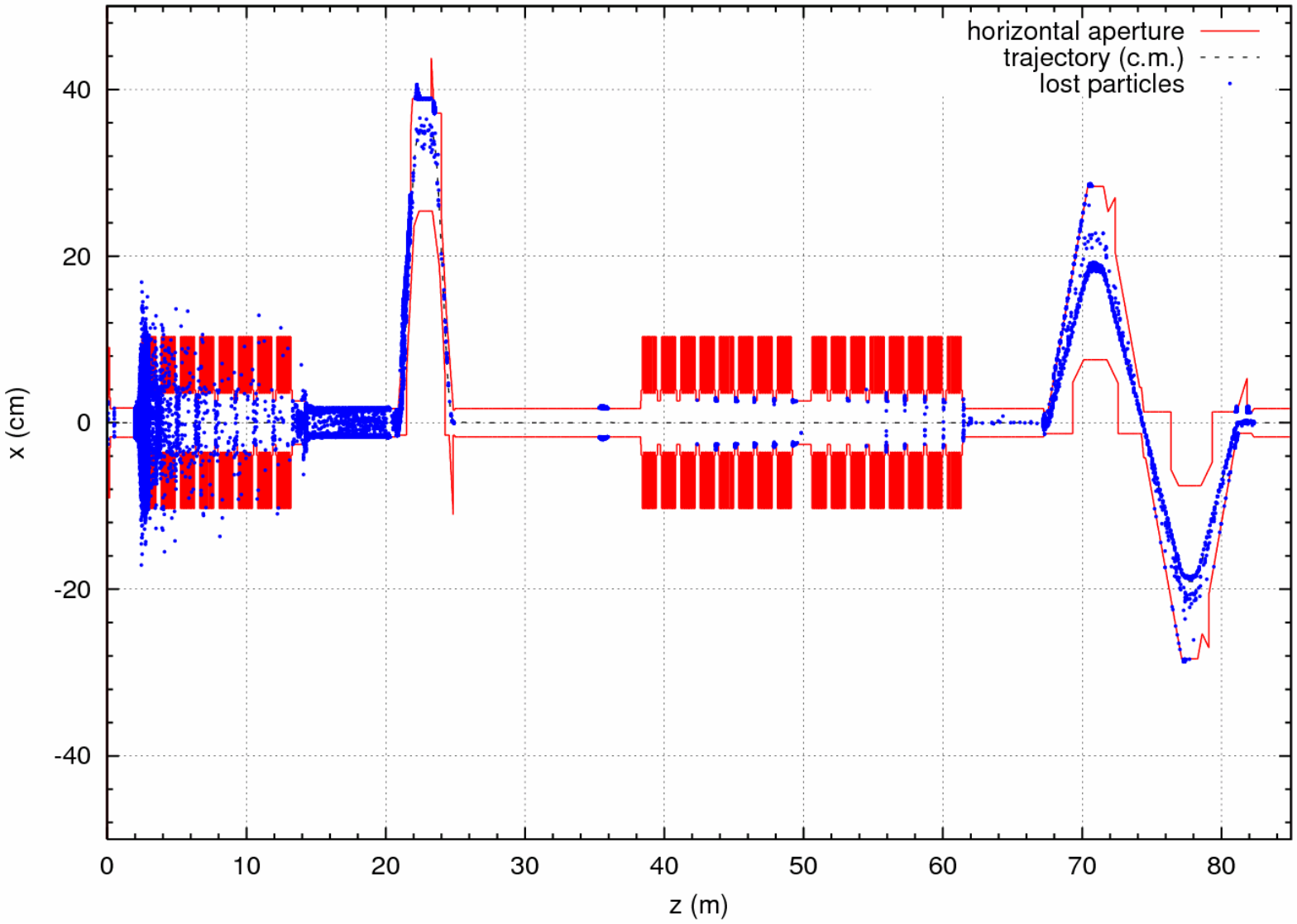
Dark Current Losses (1)



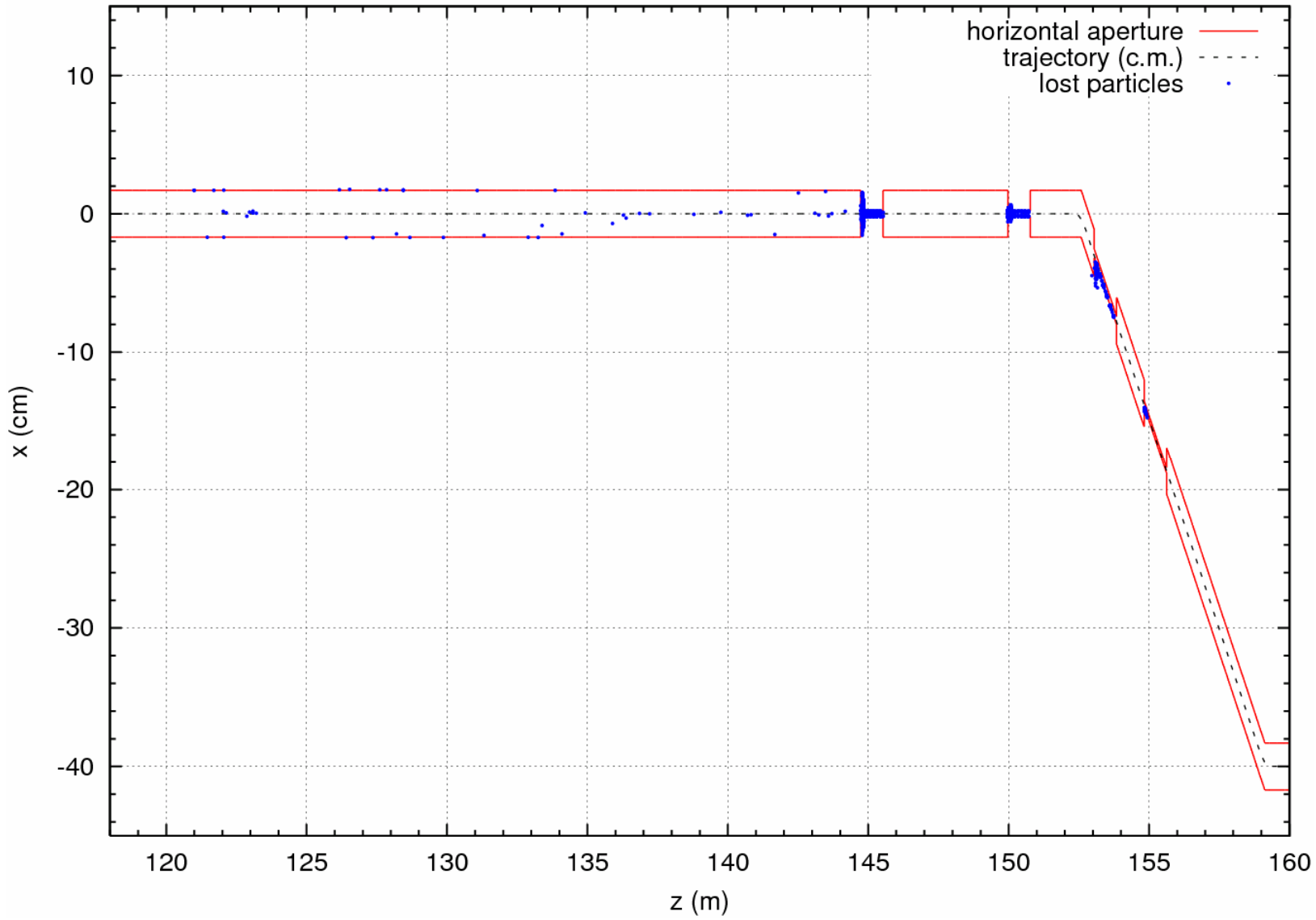
Dark Current Losses (1)



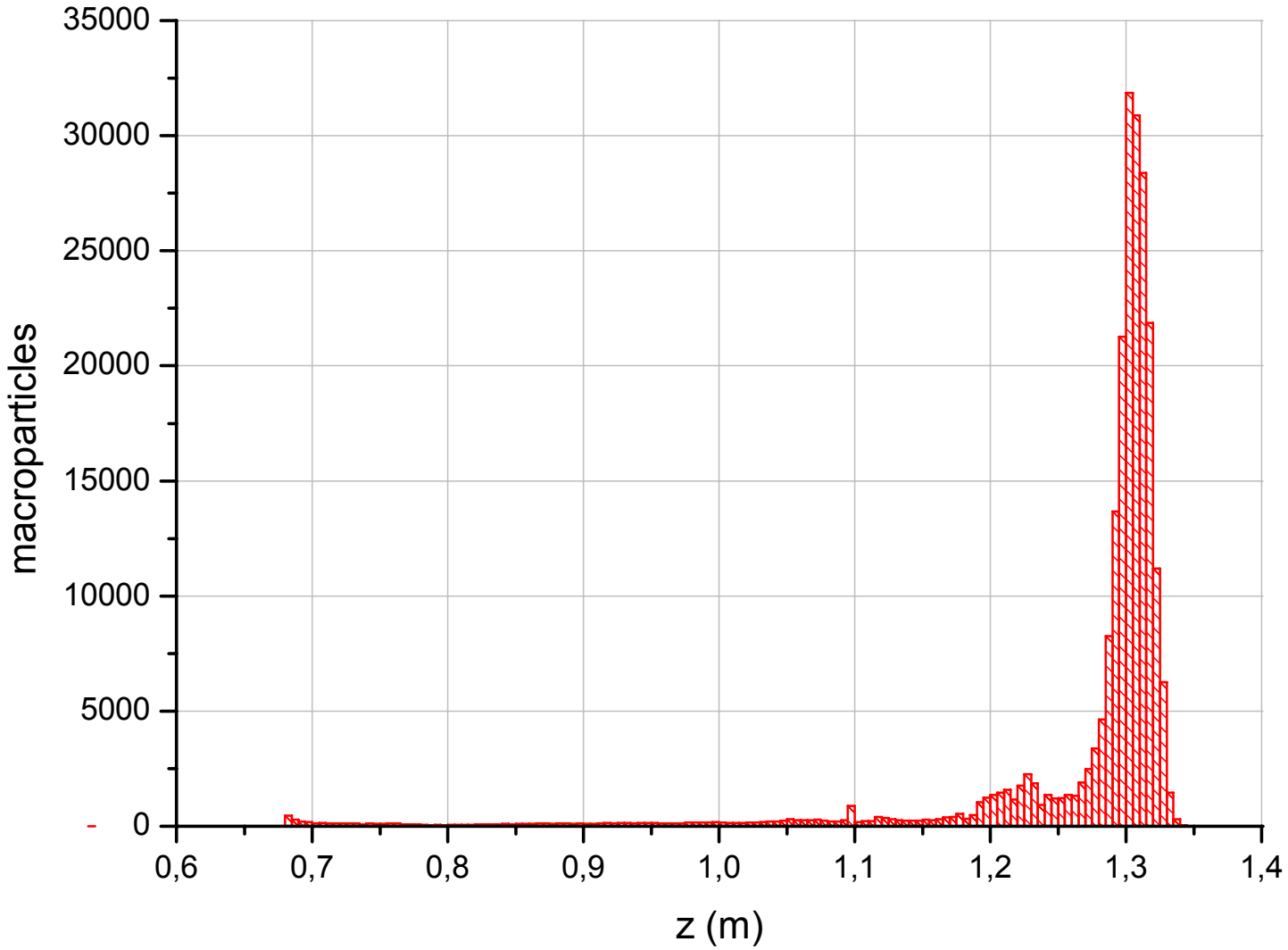
Dark Current Losses (2)



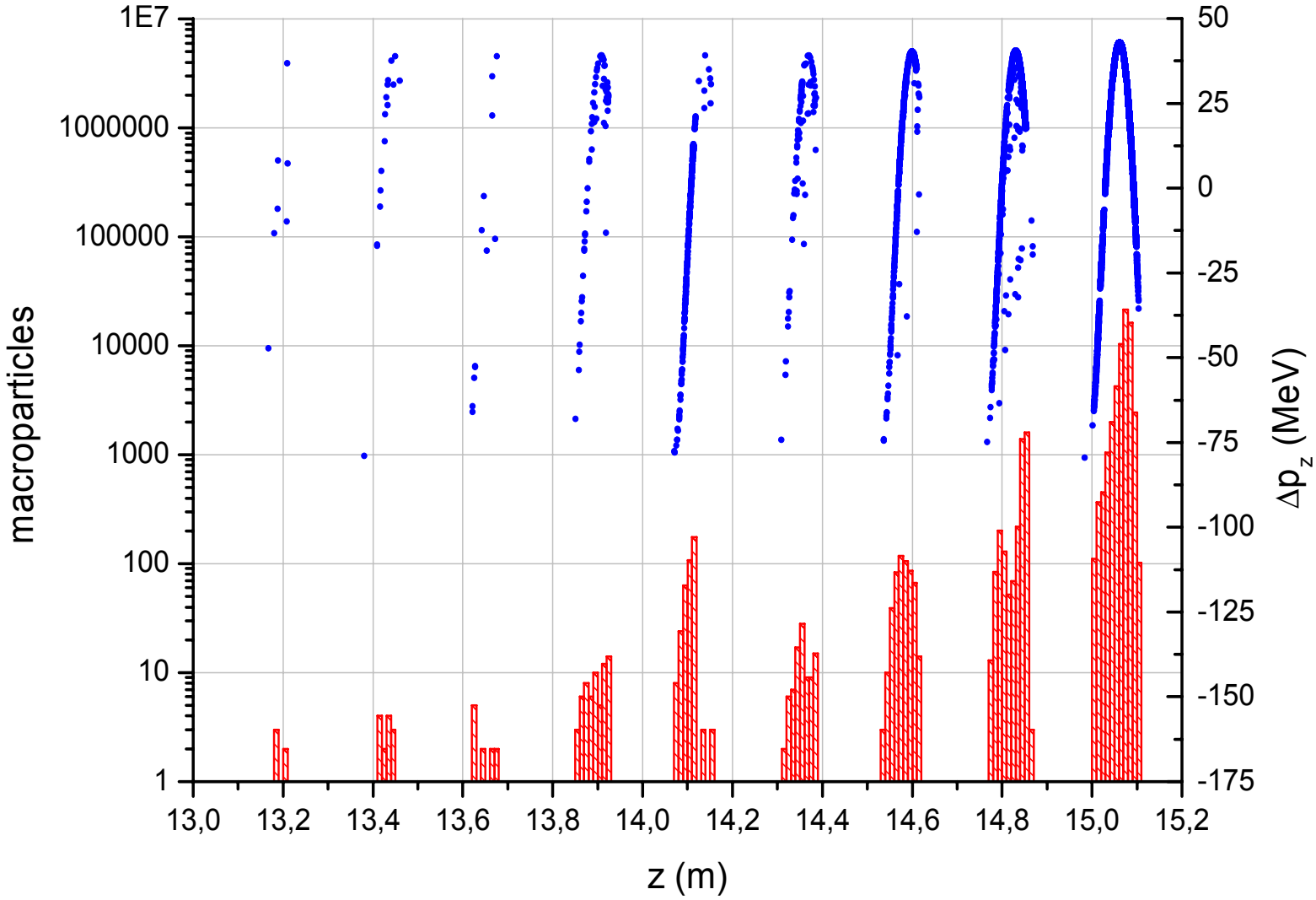
Darkcurrent Losses (3)



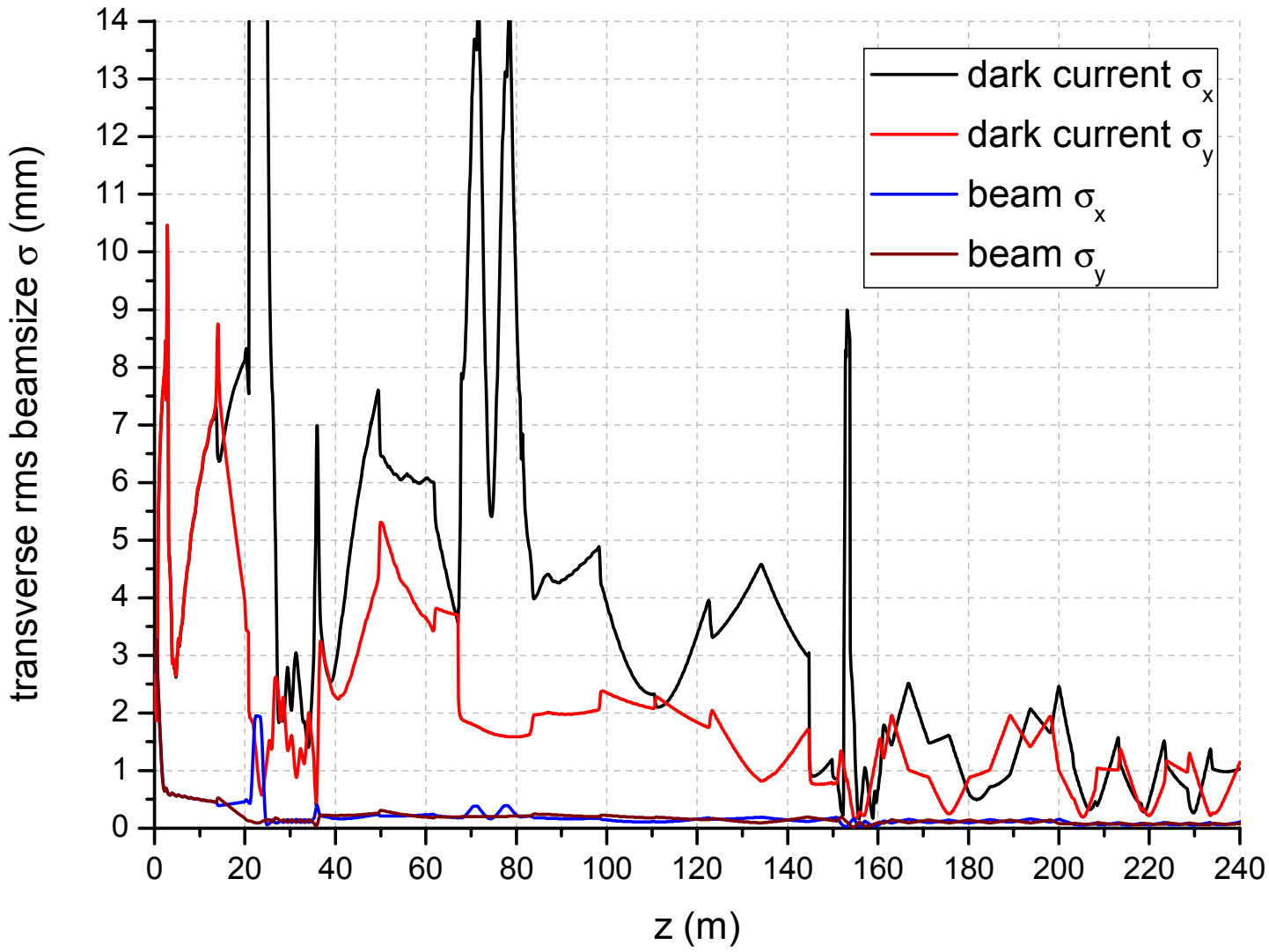
Longitudinal Profile (GUN)



Longitudinal Profile (ACC1)

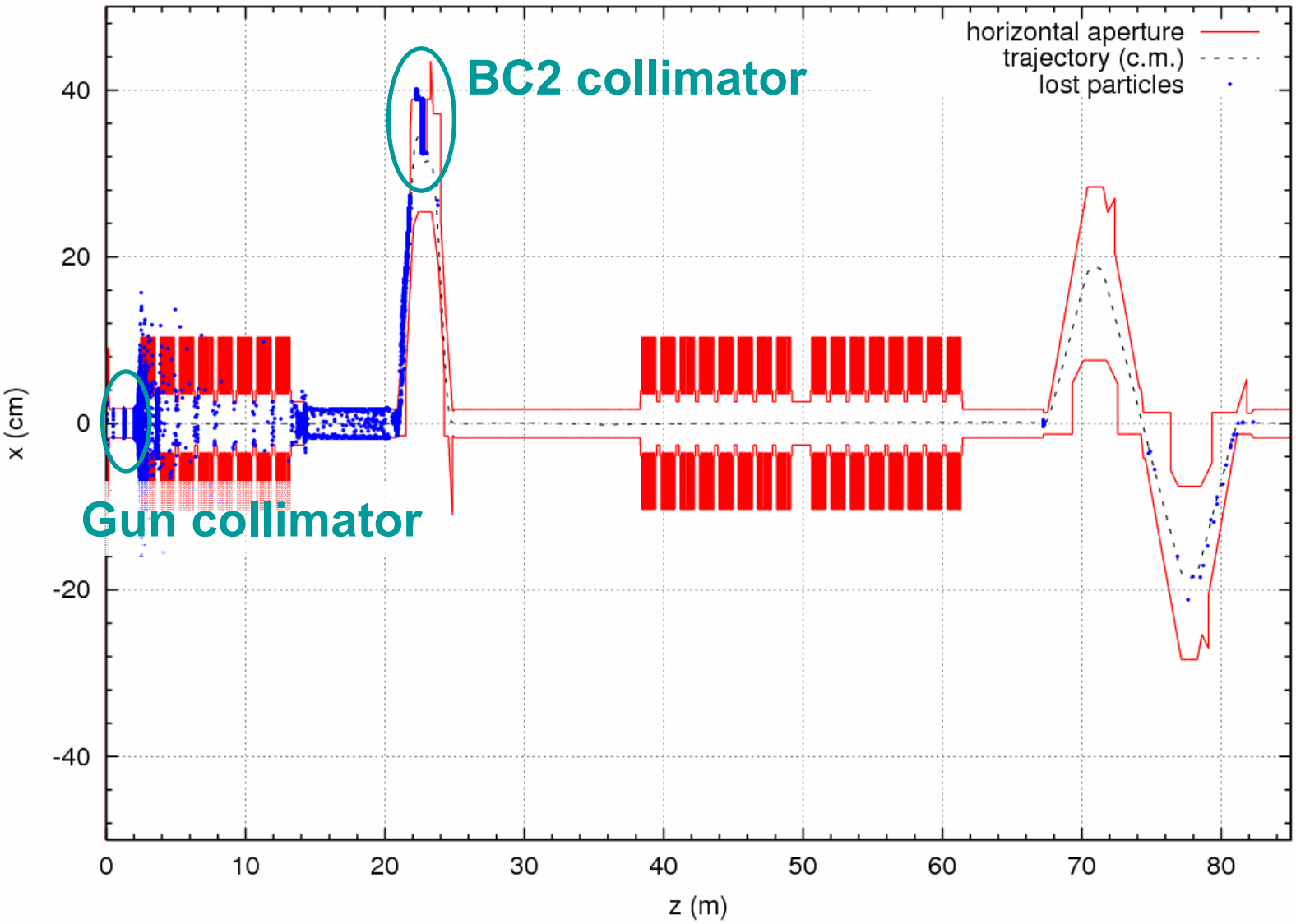


Transverse Beam Size



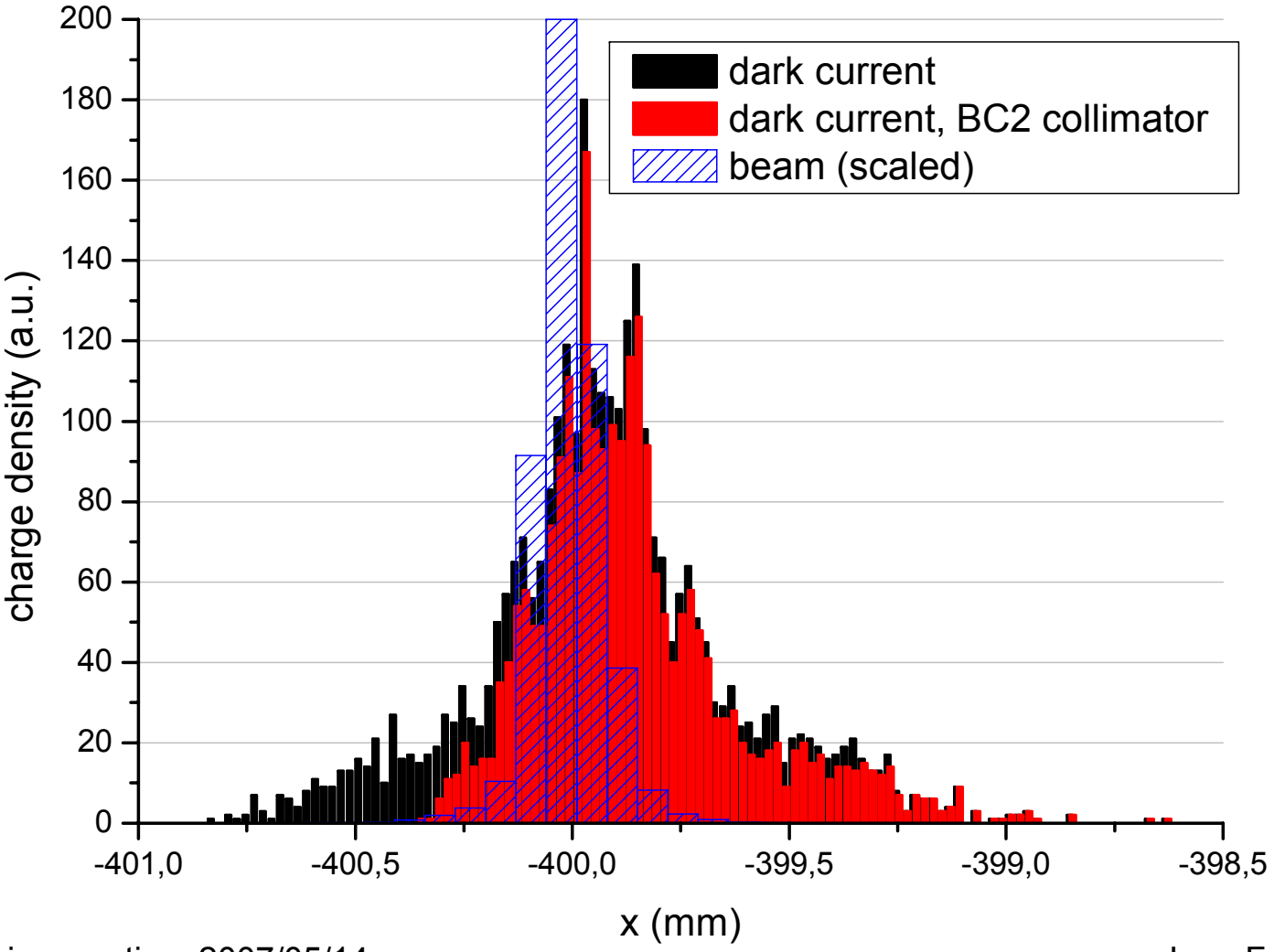
3: Counter Measures

BC2+Gun Collimators



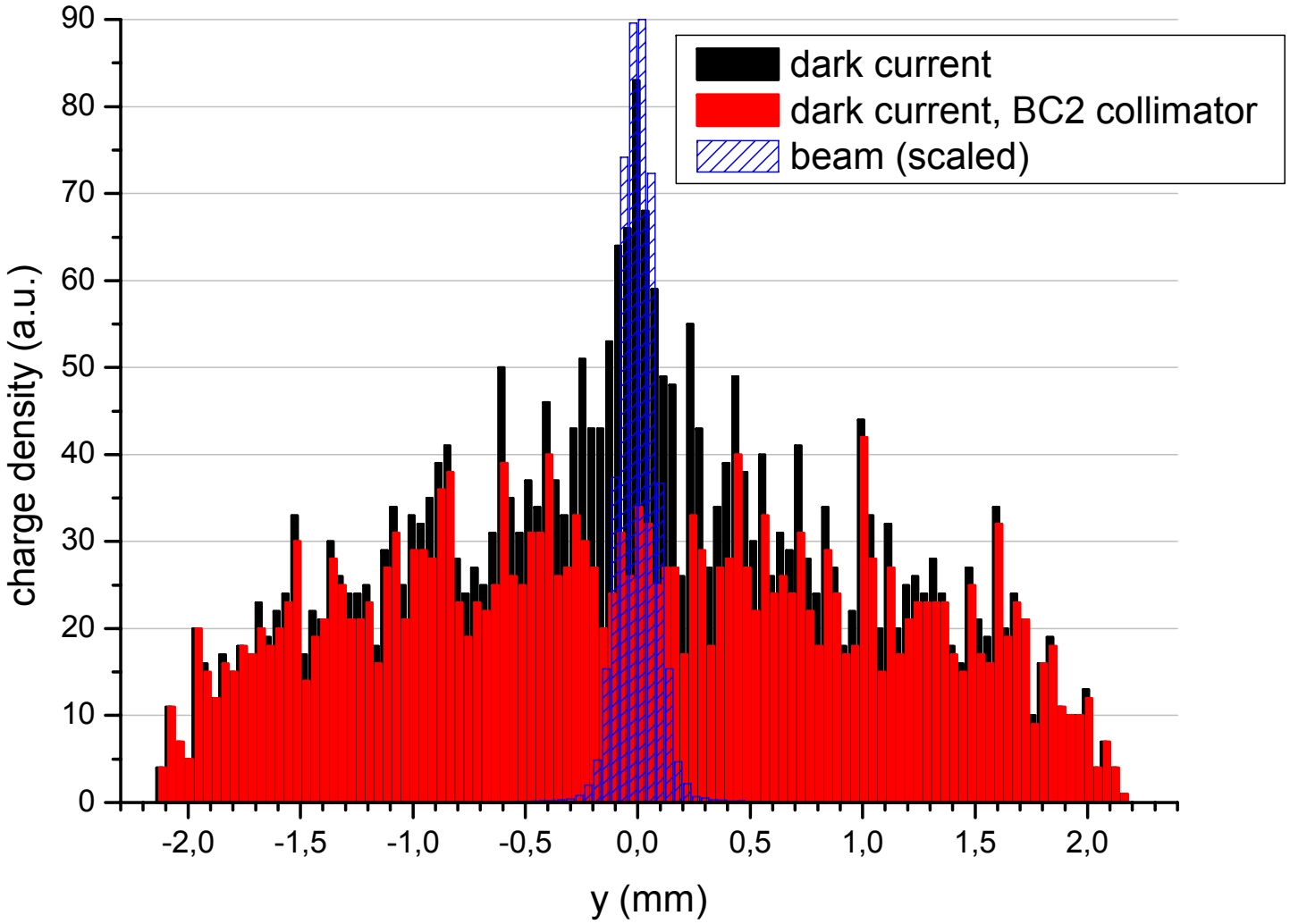
Horizontal Profiles

(in front of undulator entrance)



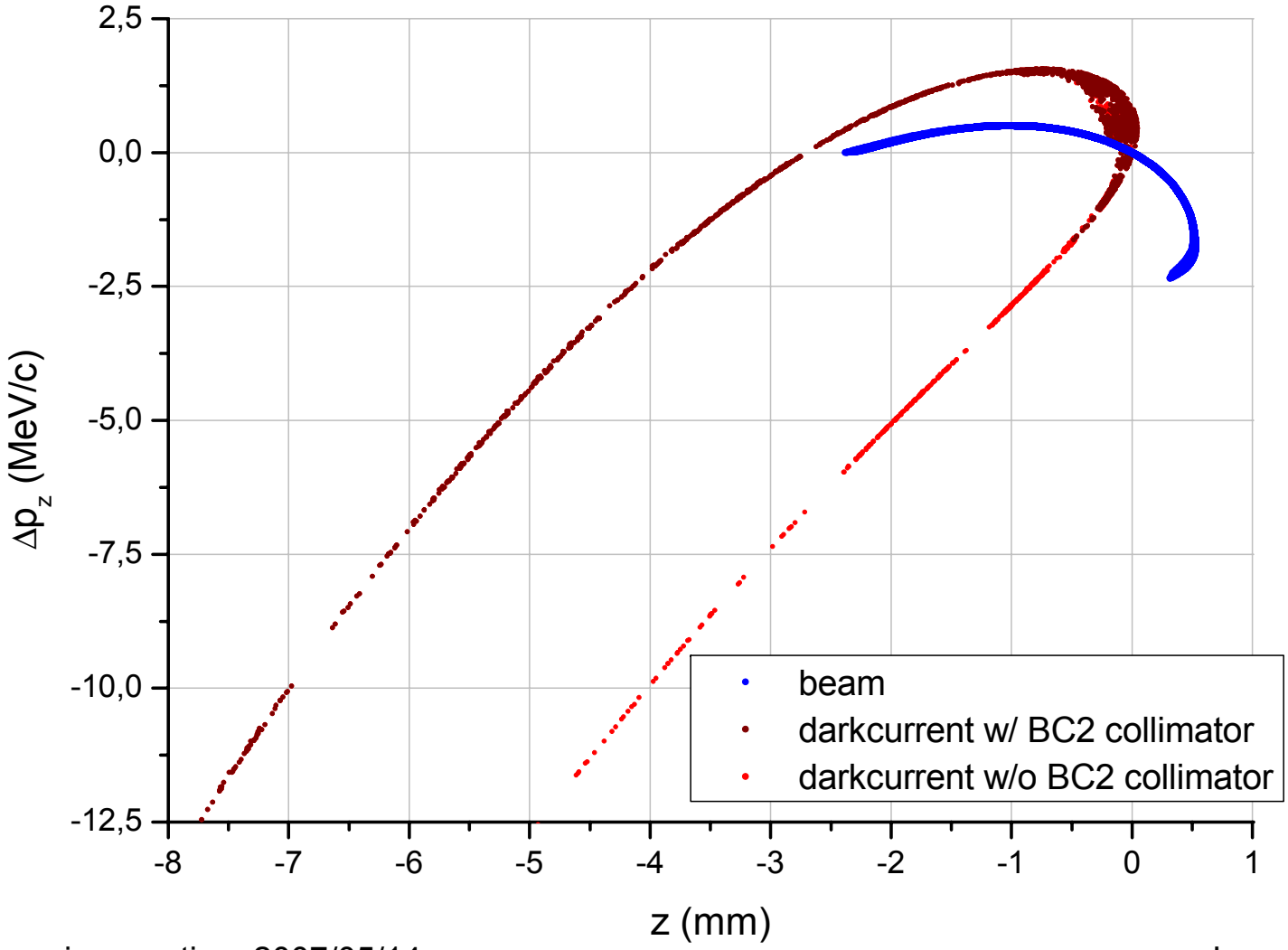
Vertical Profiles

(in front of undulator entrance)

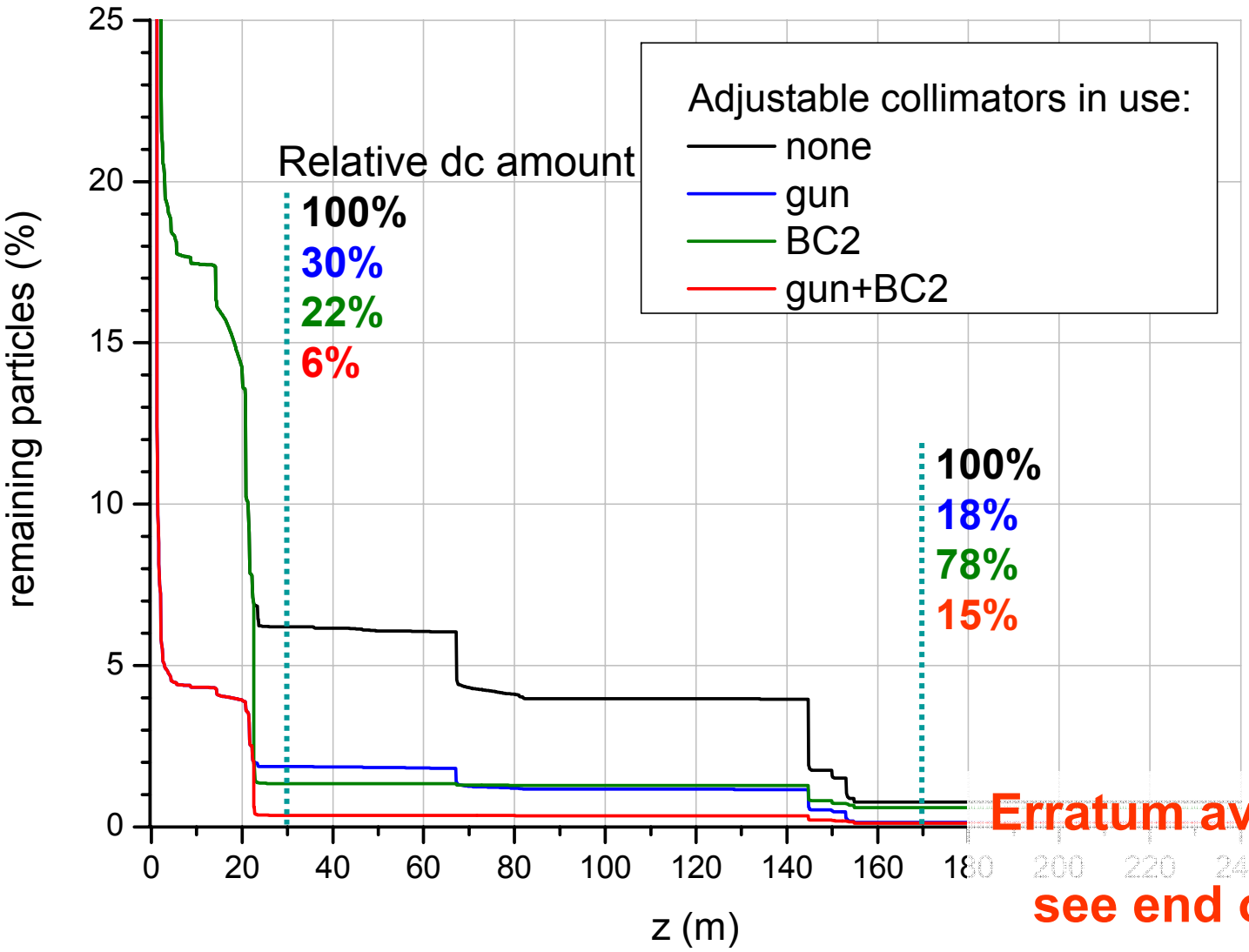


Longitudinal Phase Space

(in front of undulator entrance)



Dark Current Transmission

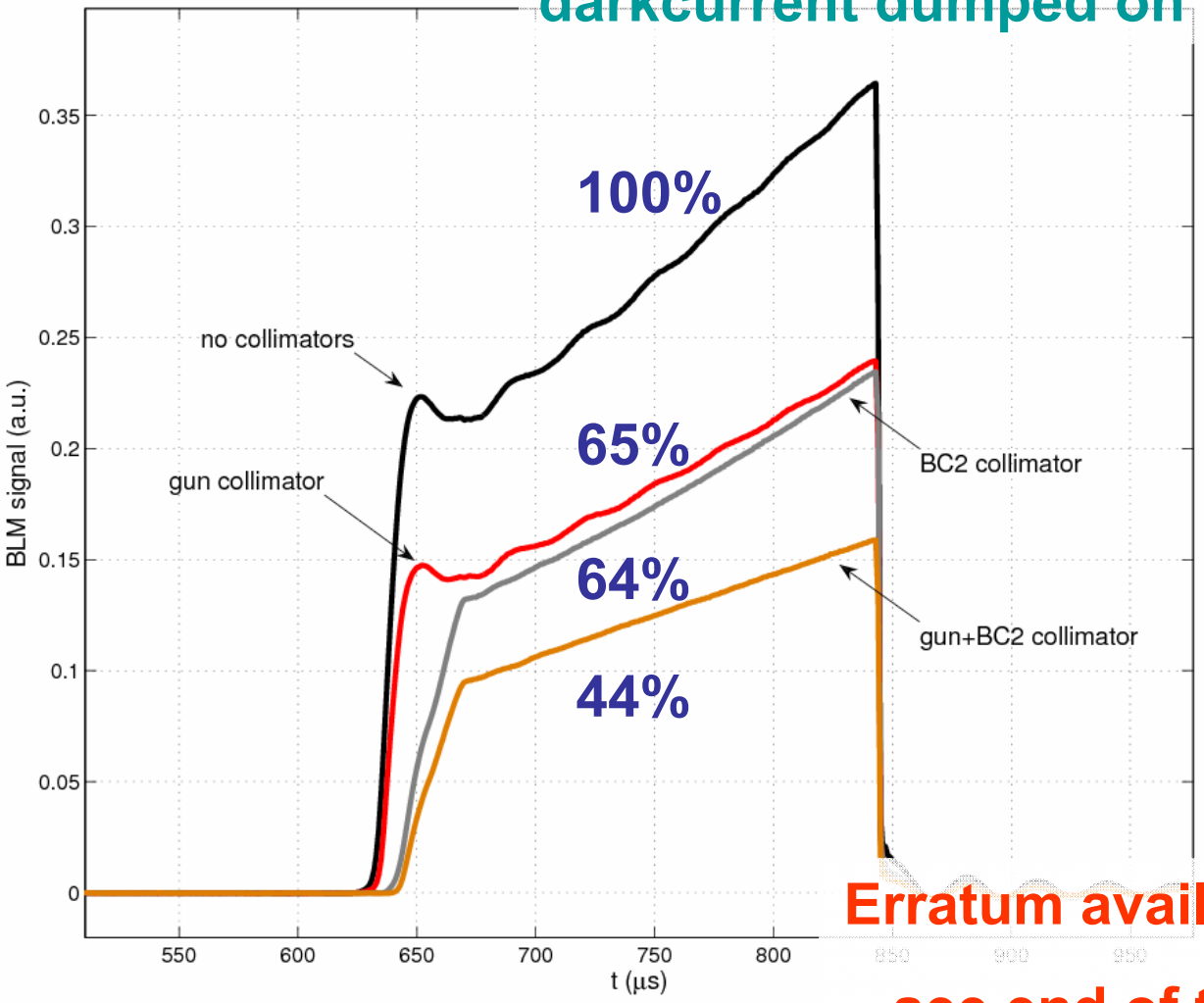


Beam Losses at 8DBC2

Simulation
- **100%**
- **30%**
- **22%**
- **6%**

Measurement
- **100%**
- **65%**
- **64%**
- **44%**

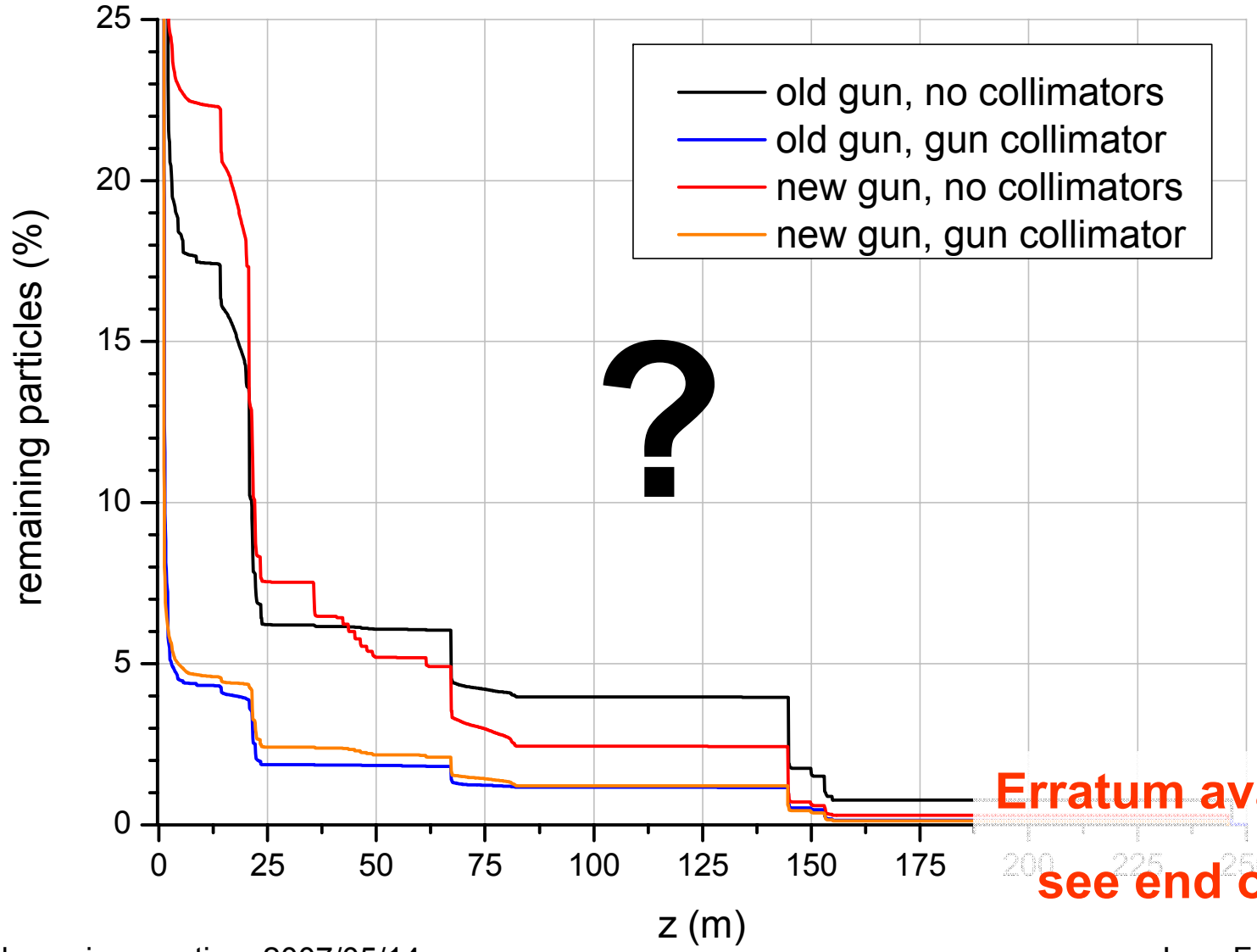
darkcurrent dumped on valve



Erratum available:

see end of talk

New Gun Layout



Erratum available:

see end of talk

Conclusion

- More work needed on simulation
  (finer step size -> include ApertureLib into Astra?)
- Measurements needed
- A usable gun collimator will reduce the activation of BC2 components considerably

Errata

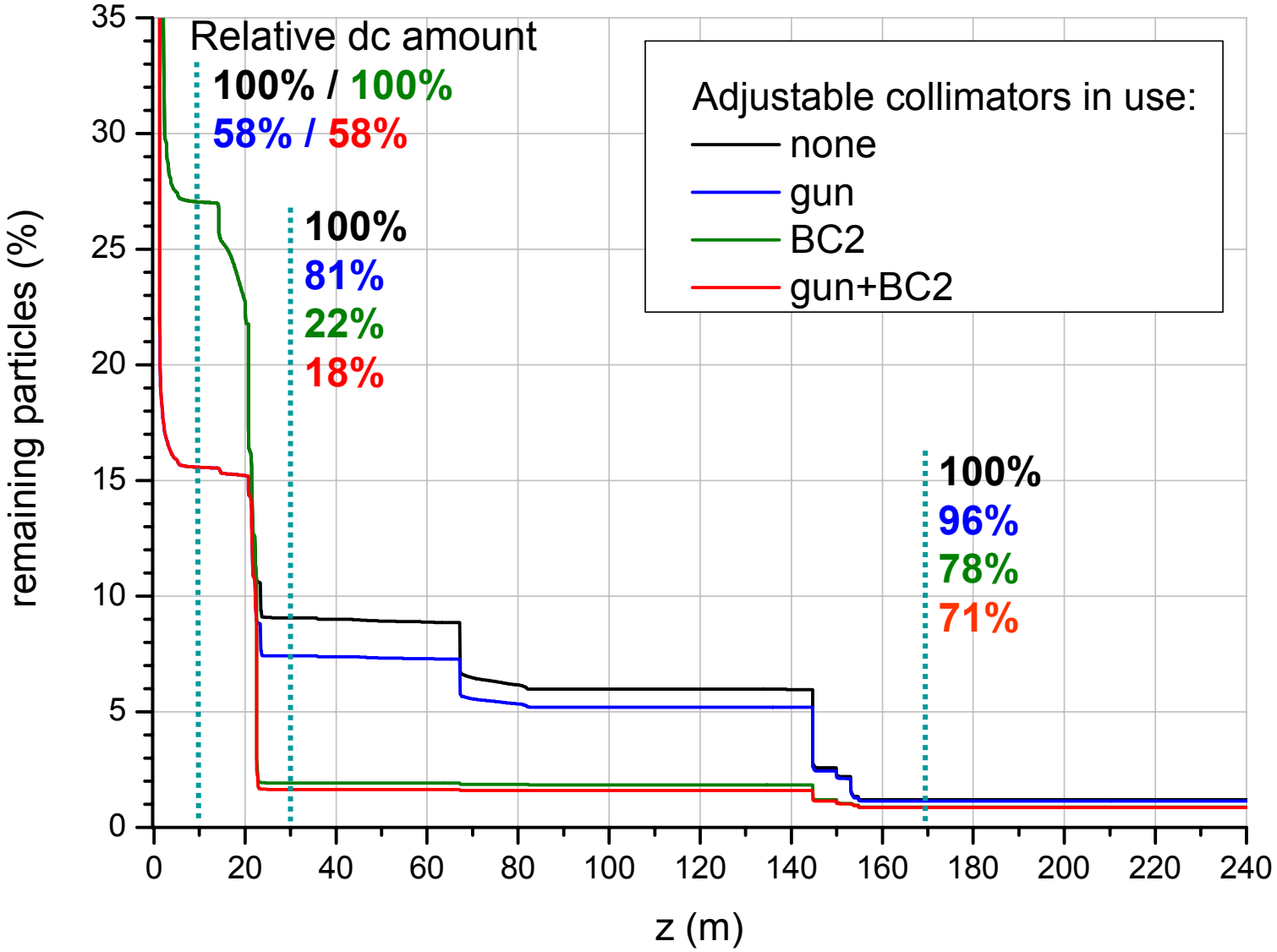
Errata

- In the original simulations, the gun collimator model had an effective length of more than 2 cm, which lead to a substantial overestimation of its efficiency. In the corrected model, the gun collimator length is reduced to about 2 mm.
- The 100% level for the dark current in the old gun layout was not calculated correctly.

Main consequences:

- Better agreement between measurement and simulation (although still not satisfying)
- The simulation confirms that the dark current output of the redesigned gun is lower than that of the old gun, as expected.

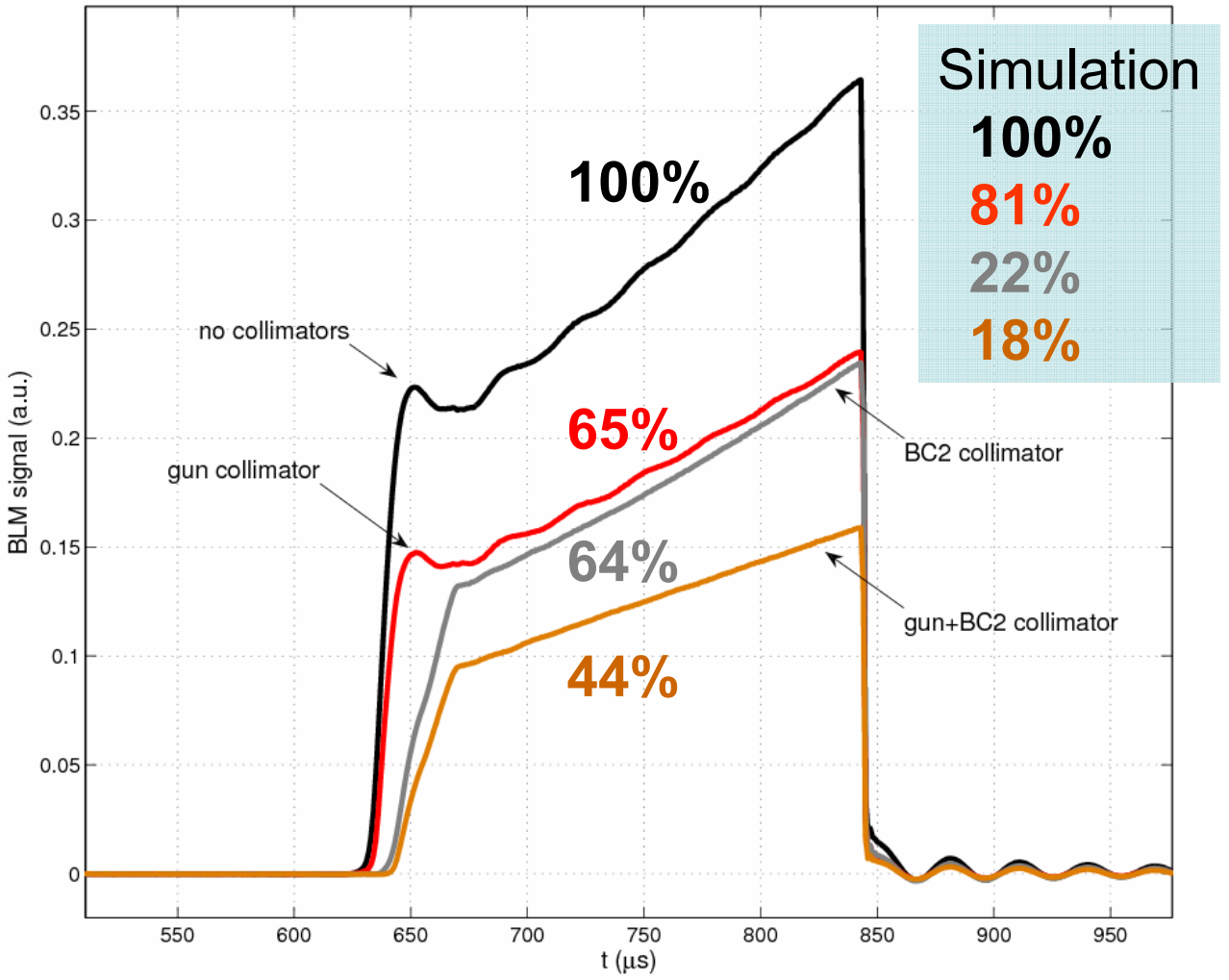
Dark Current Transmission



Beam Losses at 8DBC2

first quick-and-dirty measurement: dark current dumped on valve

- Real transverse position of BC2 collimator unclear
- Unknown contribution of ACC1 dark current
- Gun collimator is misaligned in real world
- Possible additional dark current losses by mis-steering



New Gun Layout