Code Comparison – Single Particles

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(Preliminary, v. 0.5)

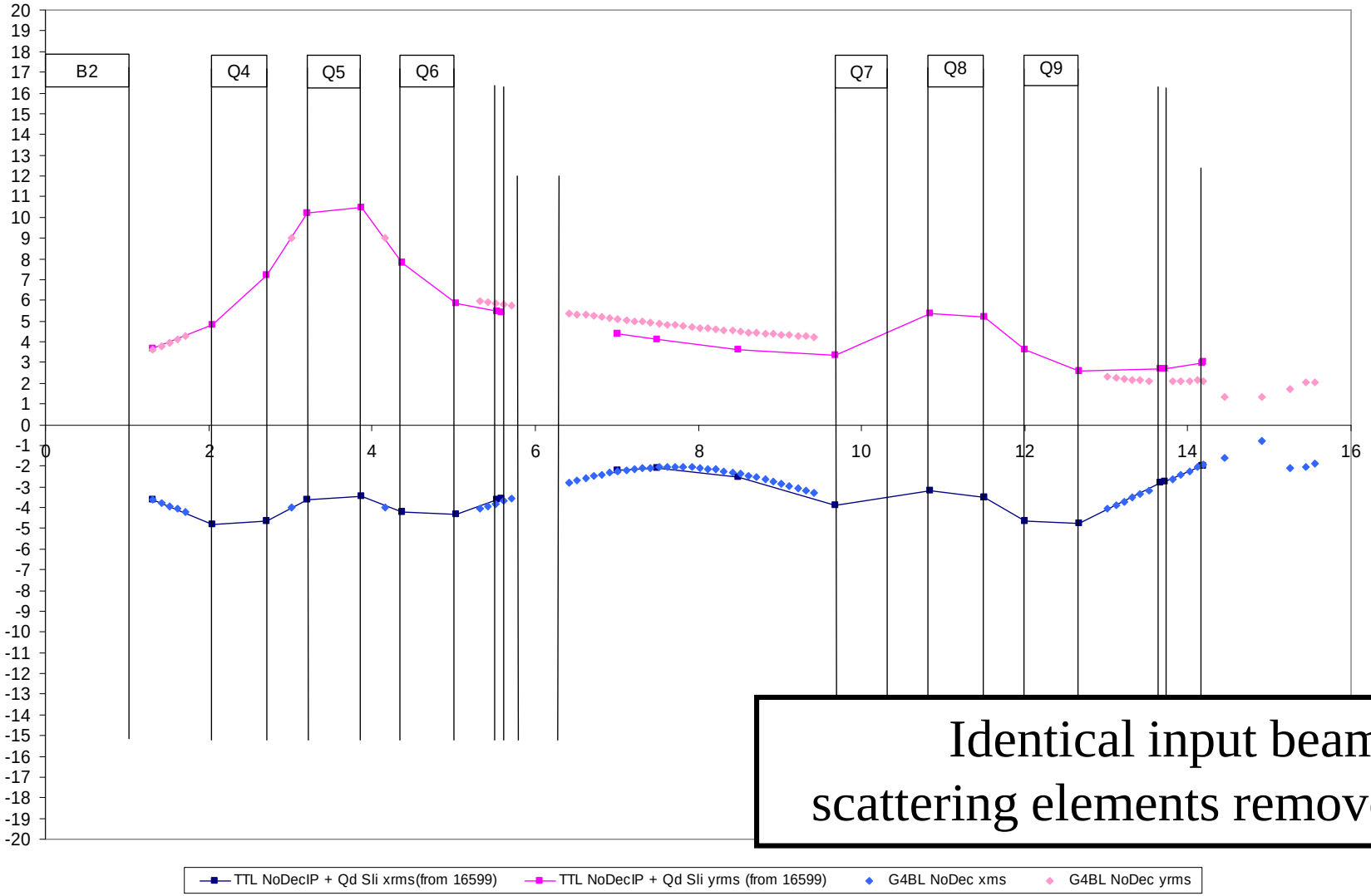
Motivation

MICE beamline simulations have been done using two codes:

- PSI Graphic **TURTLE** and **TRANSPORT** (1st, 2nd and 3rd order matrix ray tracing and beam propagation)
  - Fast (min/Mpion), well-known
- Tom Roberts' **G4beamline** (Geant4 based)
  - New, has comprehensive scattering and trajectory physics, but slow (hours/Mpion)

For the same lattice, the output beam from Turtle in 3rd order was found to have emittance of 7.1π mm rad, while that from G4beamline (G4BL) was 11.7π mm rad . Also differences in profiles:

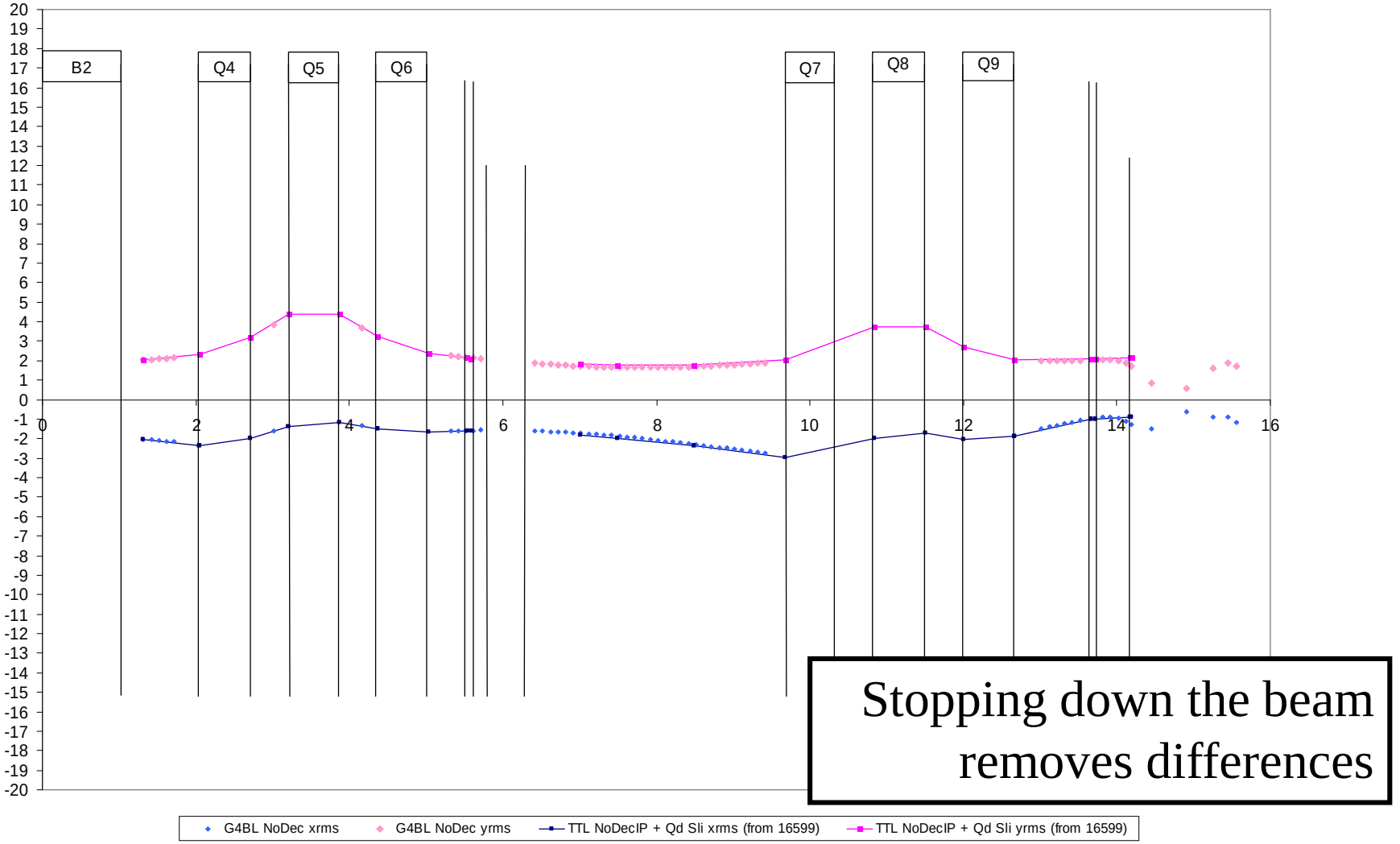
Common 30 mrad beam after B2



Identical input beams, scattering elements removed

1. http://www.isis.rl.ac.uk/accelerator/MICE/Task%20Notes%20and%20Specifications/beamline%20-%20optics/2007-06-07/TTlvG4BL_1stStage_JustNoDecData.xls

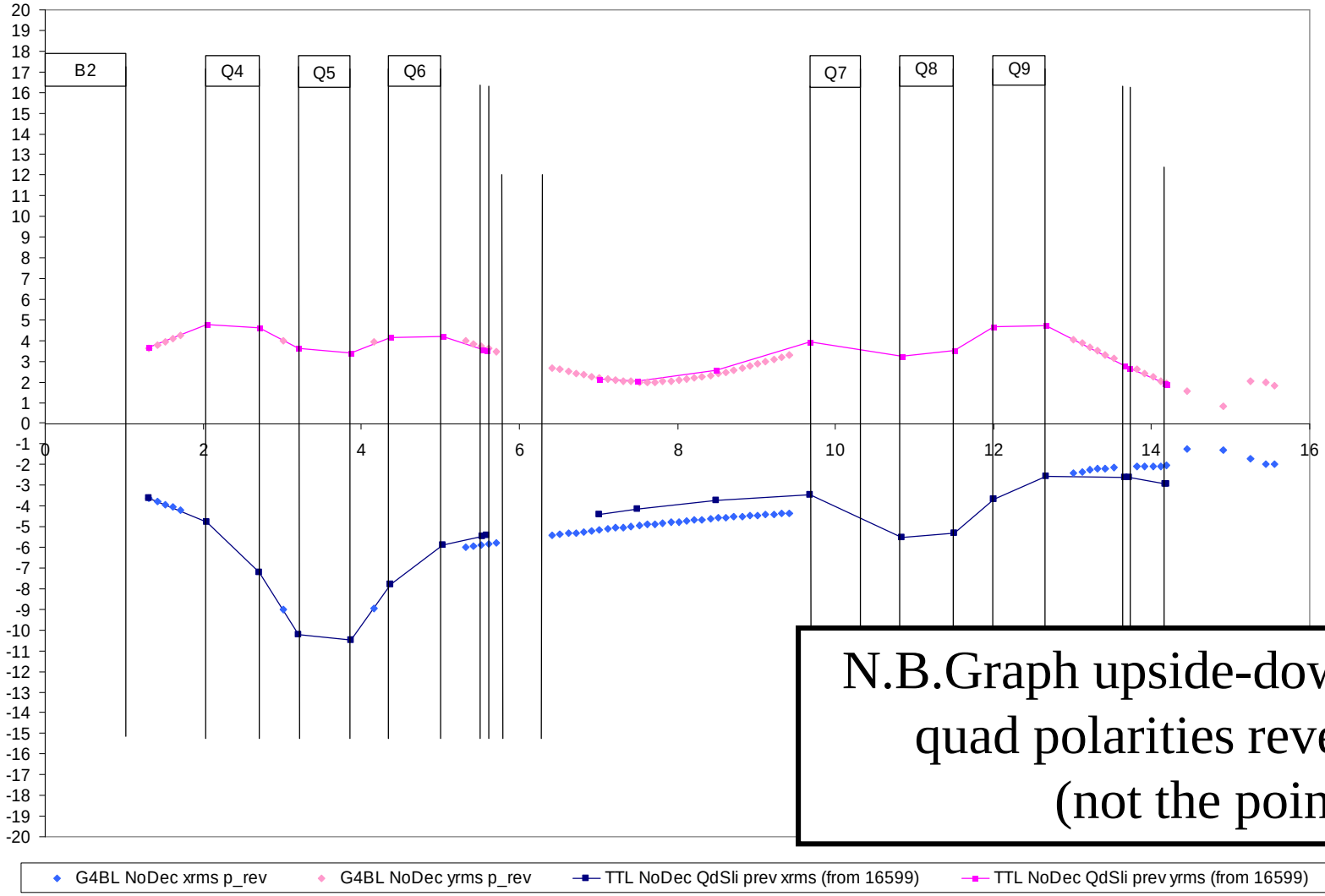
Common 10 mrad beam after B2



Stopping down the beam removes differences

1. http://www.isis.rl.ac.uk/accelerator/MICE/Task%20Notes%20and%20Specifications/beamline%20-%20optics/2007-06-07/TTlvG4BL_1stStage_JustNoDecData.xls

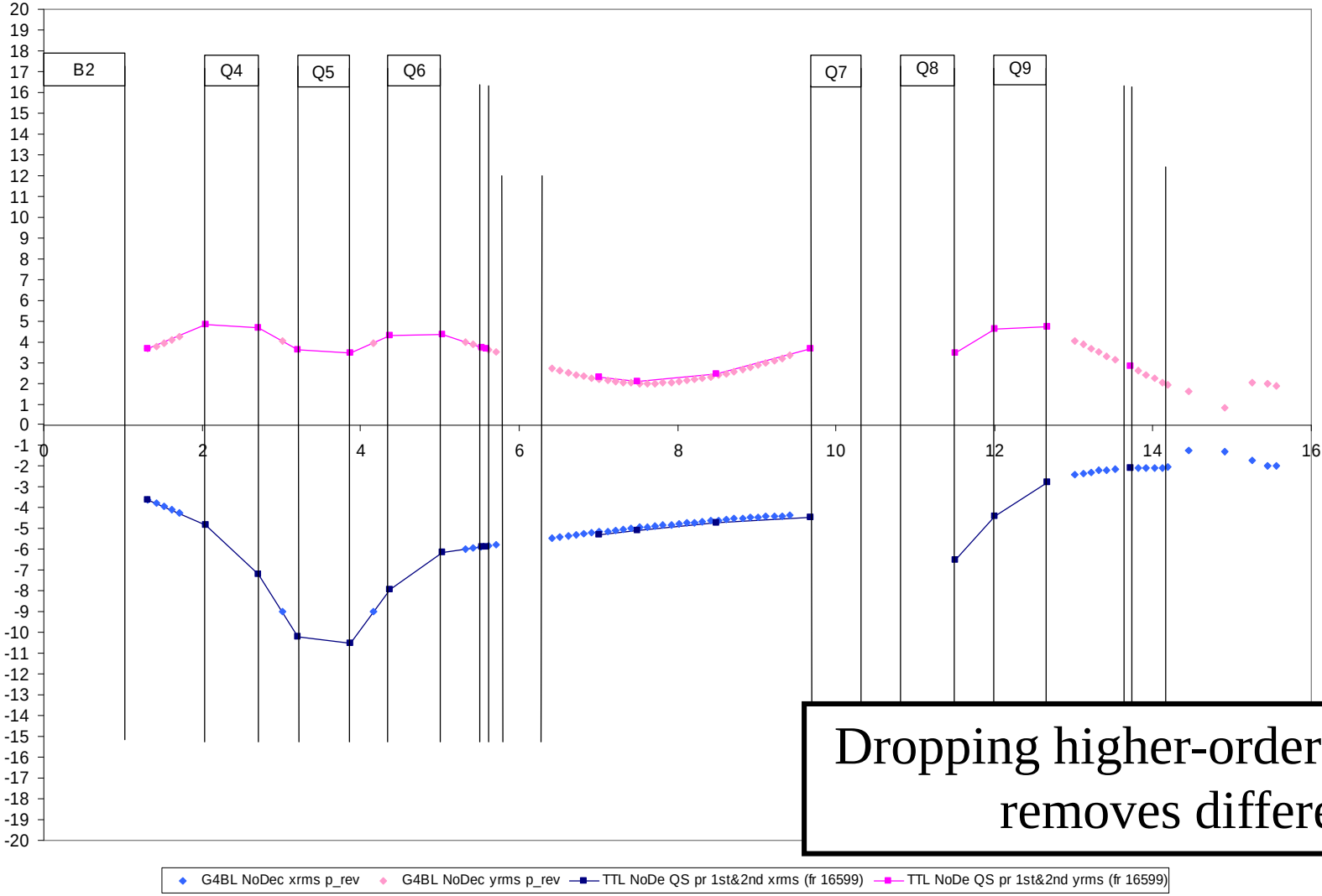
Common 30 mrad beam after B2 (rev. pol.)



N.B.Graph upside-down as quad polarities reversed (not the point…)

1. http://www.isis.rl.ac.uk/accelerator/MICE/Task%20Notes%20and%20Specifications/beamline%20-%20optics/2007-07-24/TTlvG4BL_1stStage_JustNoDecData_postCM18_2.xls

Turtle only in 2nd order (rev. pol.)



Dropping higher-order term removes differences

1. http://www.isis.rl.ac.uk/accelerator/MICE/Task%20Notes%20and%20Specifications/beamline%20-%20optics/2007-07-24/TTlvG4BL_1stStage_JustNoDecData_postCM18_2.xls

Single particle tracks - quadrupoles

Have sent groups of single particles through a single MICE quad (Q4) with correct aperture, field strength, muon momentum etc.
But: no fringe fields, and no air.

Tested a series of input cases starting 2m before the quad, and looked at transverse momentum after the quad.

For “focussing”, the muon trajectories are confined to the focussing (*x*) plane, and the values of *x’* after the quad are compared with a reference *x’*.

For “defocussing” the inbound muons start from the corresponding locations along the *y* axis, and their eventual *y’* is compared with a reference *y’*.

Code comparison - quadrupoles

Have compared Turtle[1] running in 1st and in 3rd order mode with Microsoft Excel implementations of the 1st order equations (e.g. Carey or Banford book) and of the 3rd order equations, both Smith's[2] as printed (incorrect) and the corrected versions[3]

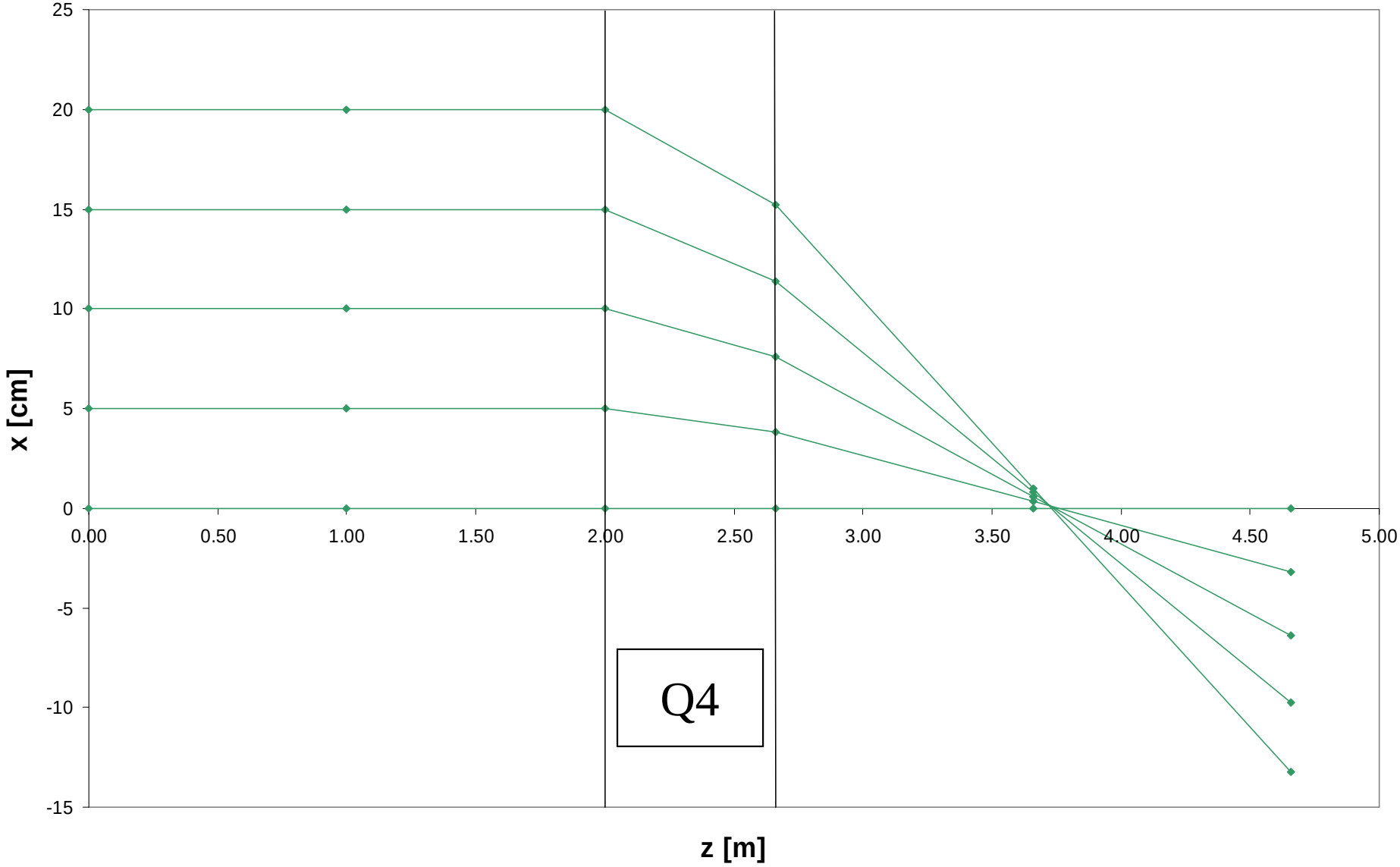
1. Turtle: TurtleNT.exe computational part for Turtle Framework, v. 2.45 compiled by U. Rohrer (PSI), 22-Mar-2005
2. D.L. Smith: "Focusing Properties of Electric and Magnetic Quadrupole Lenses" *NIM* **79** pp.144-164 (1970)
3. G.E. Lee-Whiting: "Third-order aberrations of a magnetic quadrupole lens" *NIM* **83** pp.232-244 (1970);
   G.E. Lee-Whiting: "Comparison of calculated third-order aberrations of a magnetic quadrupole lens" *NIM* **99** pp.609-610 (1972)

Input Cases

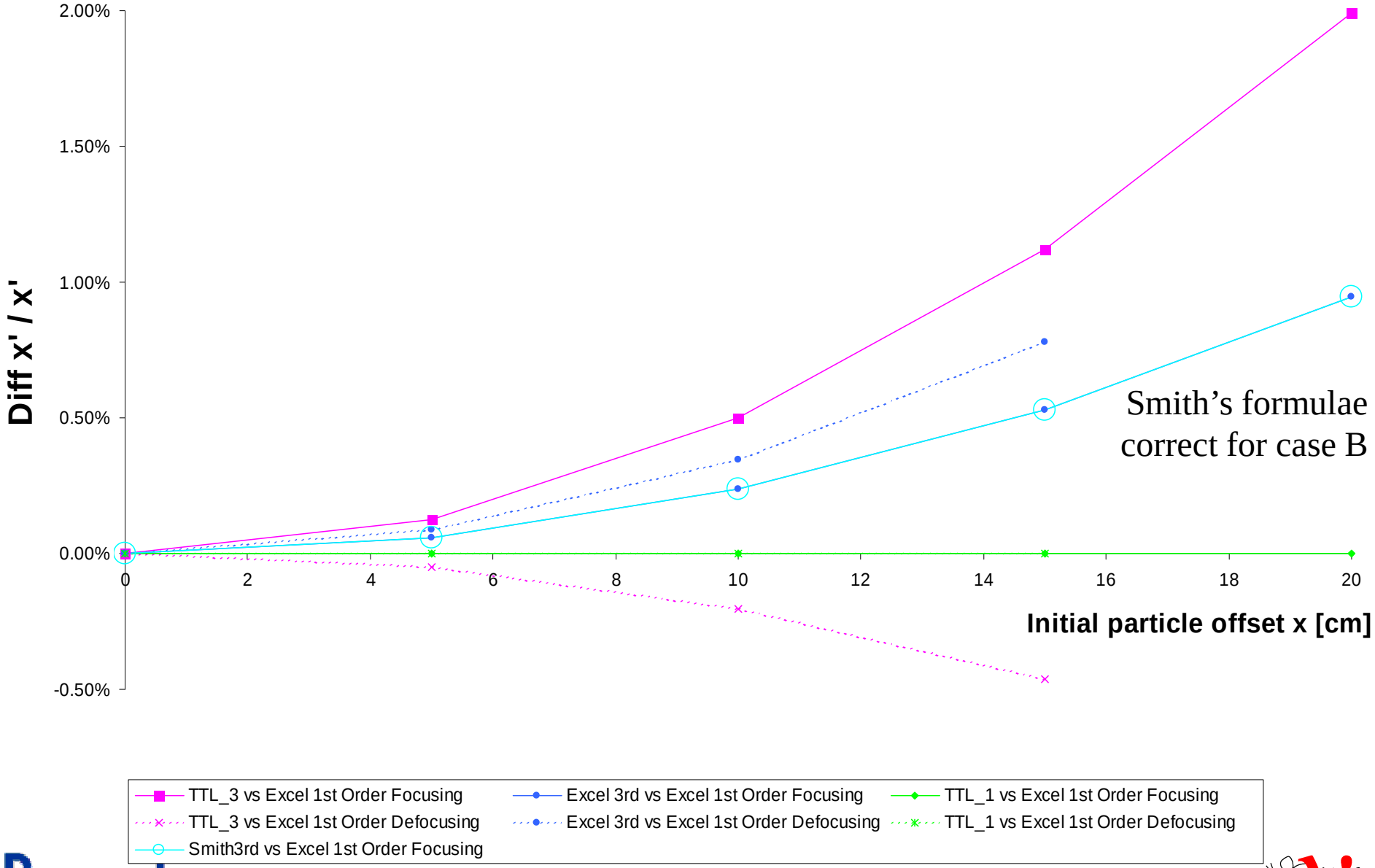
In the following slides, the geometry for each case is illustrated by the trajectories in just the focussing plane (from 3rd order Turtle), followed by a graph showing the differences in *x'* (or *y'* for defocussing) using the Excel 1st order model as the reference (an arbitrary choice).

It will be seen that cases B and H have been chosen such that the initial values of *x* or *x'* (or *y* or *y'*) are zero, which drastically simplifies the 3rd order calculations, allowing Excel's results to be confirmed by hand.

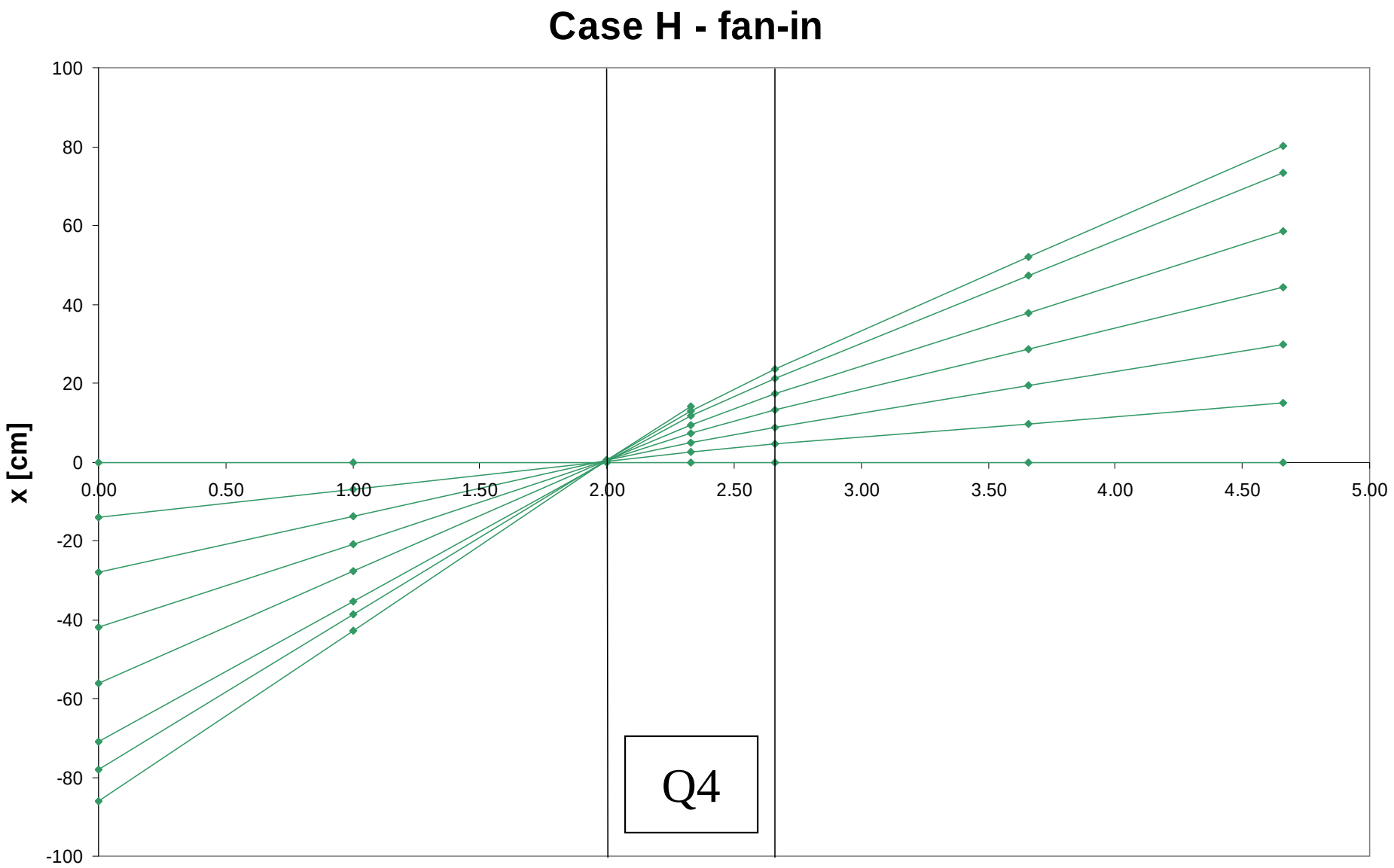
Case B - Collimated axial beam



Case B - Difference in final x' as we go off axis

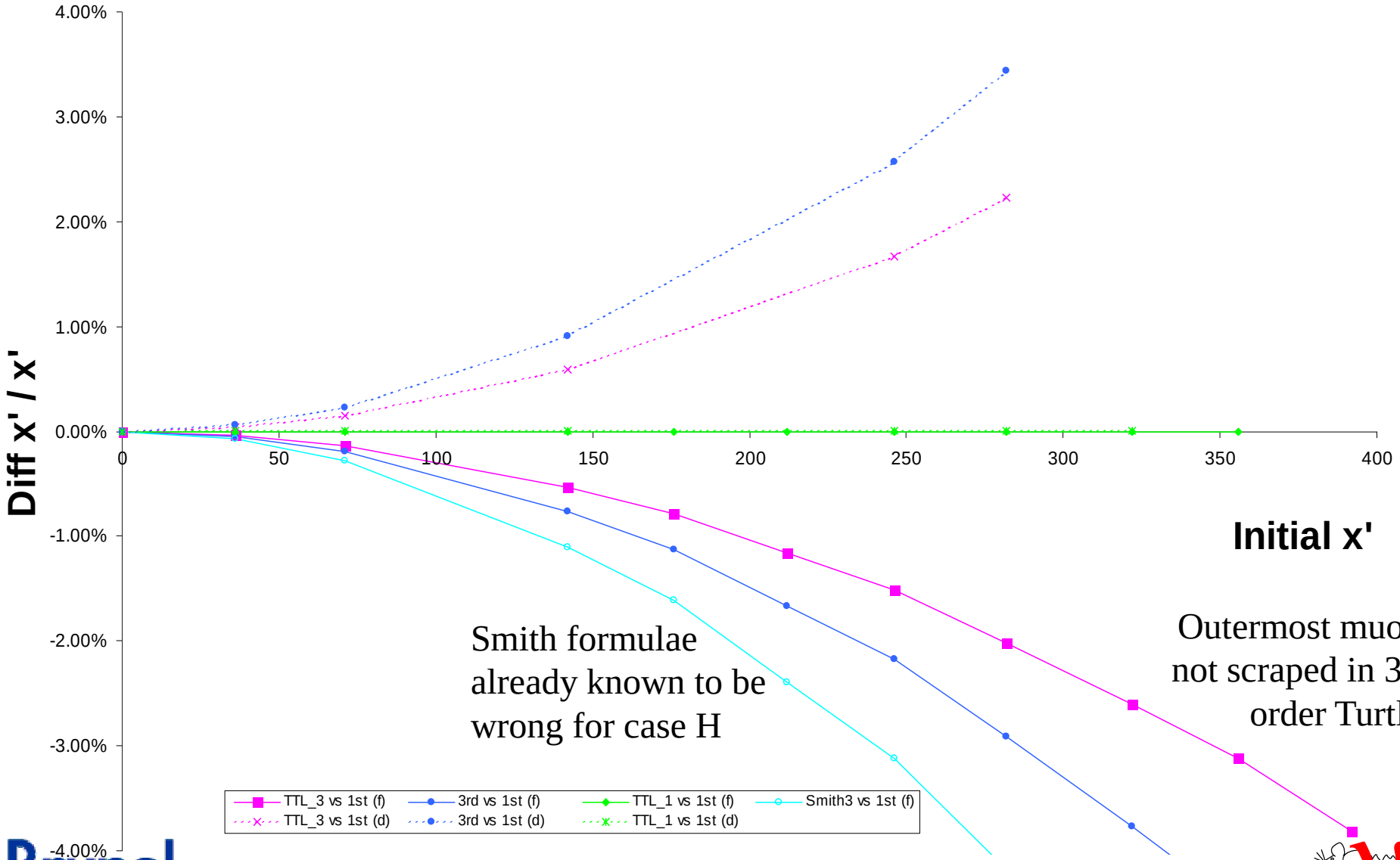


Case H - Converging group, *x'* 0 to 432 mrad



Converging group, *x'* 0 to 432 mrad

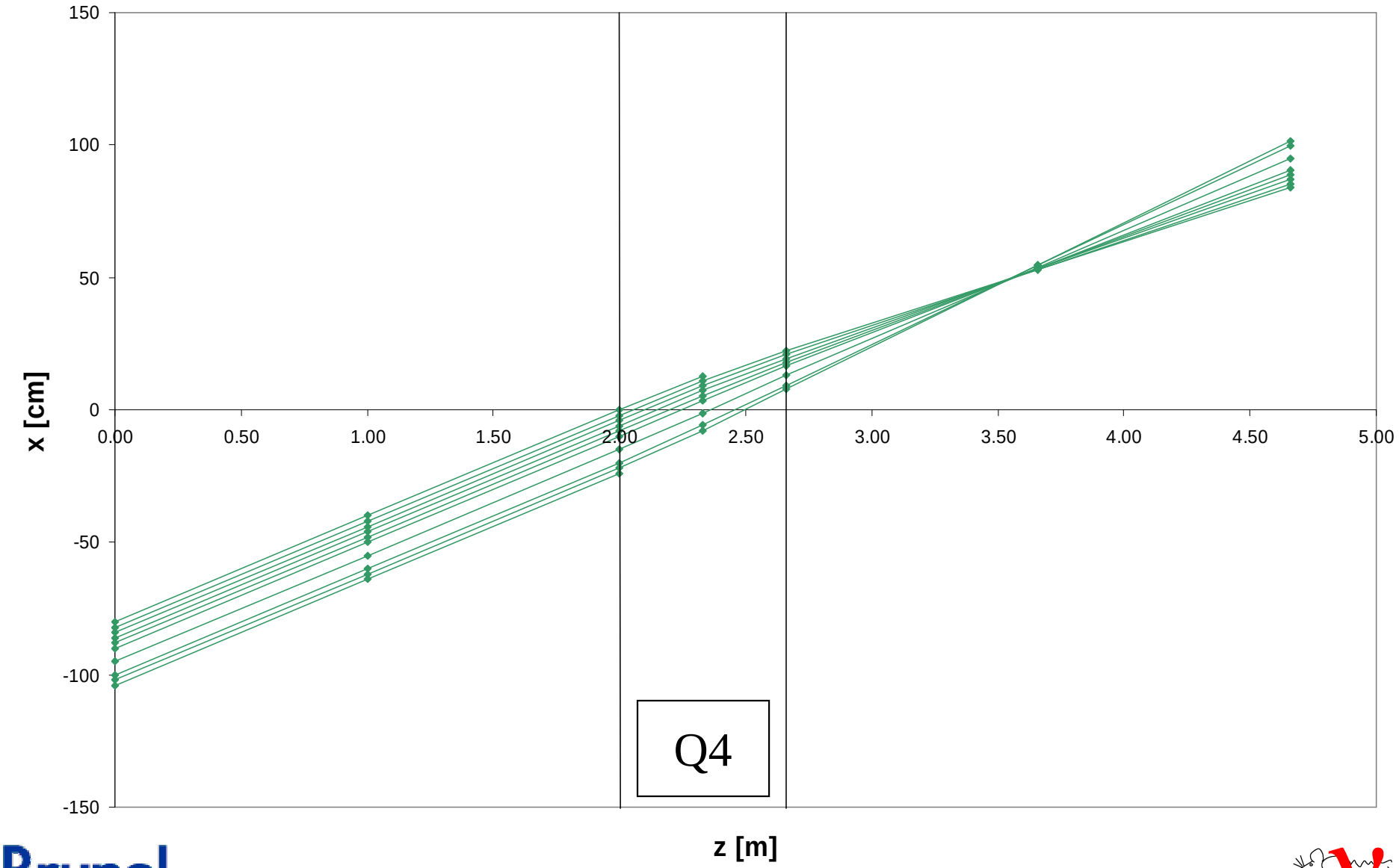
Difference in final x' as we increase x' at entry



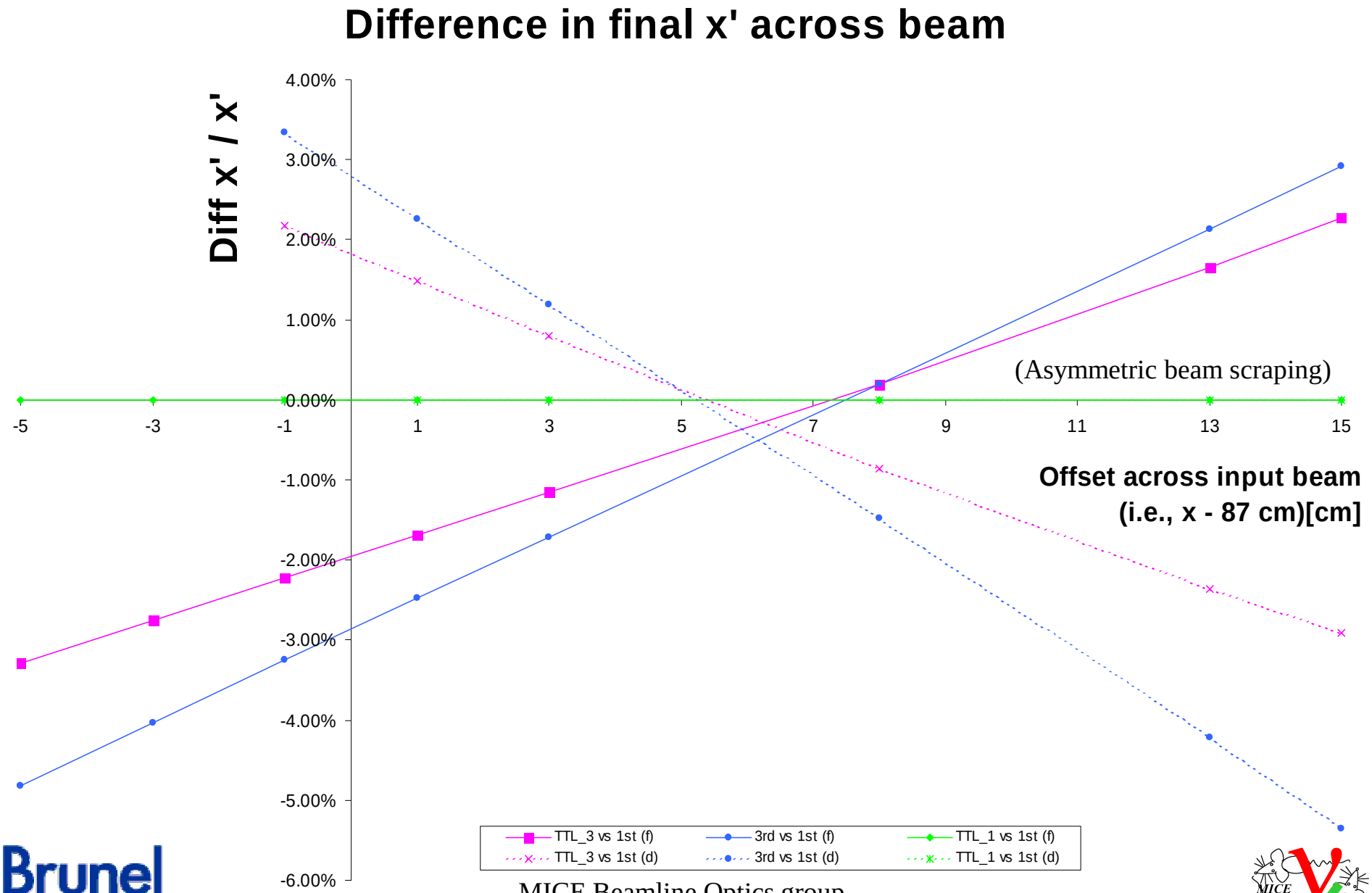
Smith formulae already known to be wrong for case H

Outermost muon not scraped in 3rd order Turtle

Case I - Off axis beam – *x'* in is 400 mrad



Off axis beam – *x'* in is 400 mrad



Conclusions

The two 1st order models give near-identical results; confirms 1st order Turtle is arithmetically correct.

The contributions of the 3rd order terms are on the scale of about ~ 1%.

The Smith 3rd-order formulae as printed give results that differ both from those from the "corrected" (Lee-Whiting) versions *and* from the 3rd-order Turtle implemetation.

The "corrected" 3rd-order and Turtle 3rd-order results *also* do not agree! Not clear why.