interaction of macroparticles with the LHC proton beam

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simulate the macroparticle trajectory, charge state and resulting beam lifetime

assume mass, density, initial position and charge state

forces: gravity, beam electric field, electric image charge

charging from ionization

beam loss due to nuclear interaction (cross section)

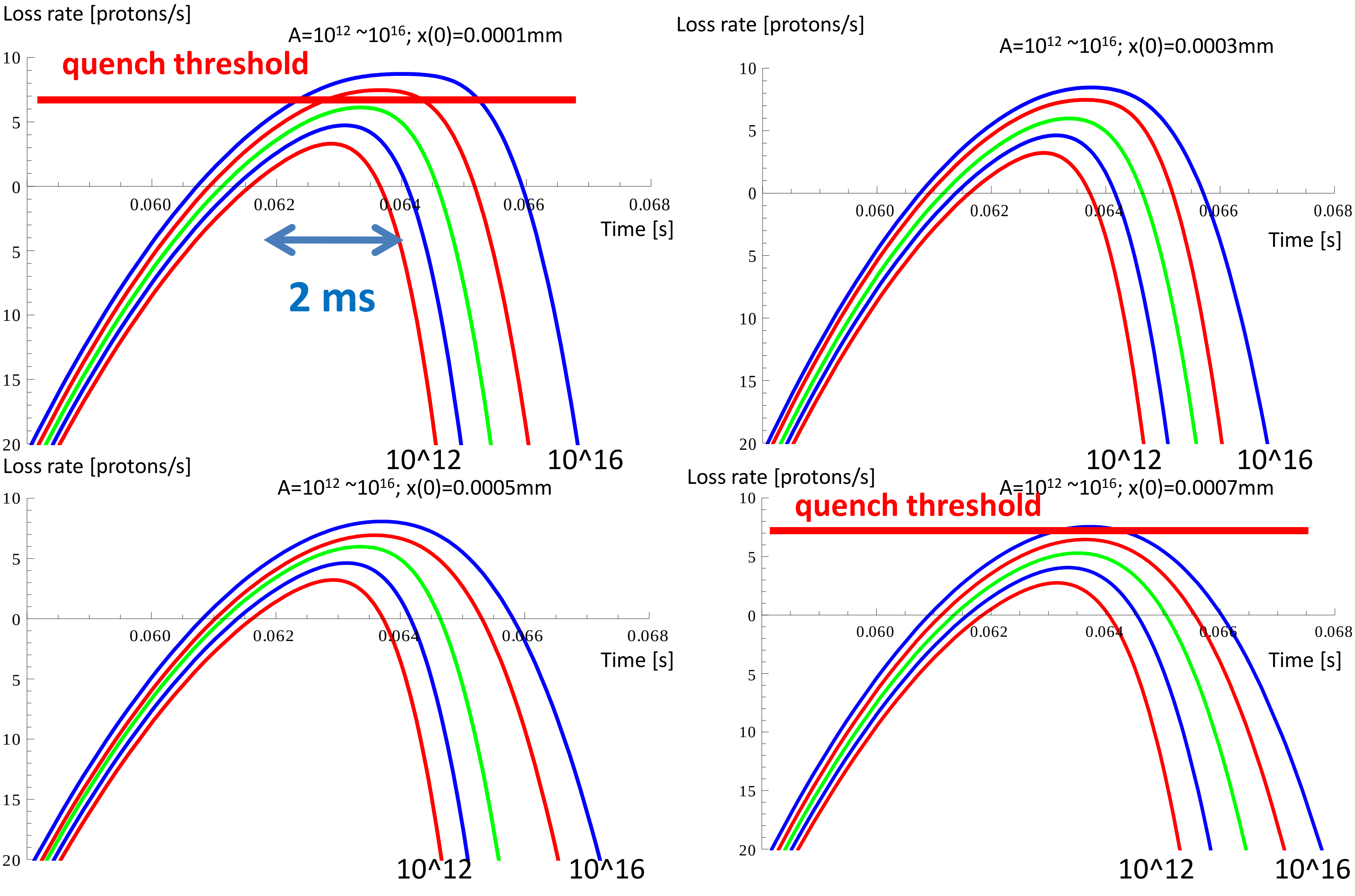
quench threshold ~ a few 10^7 p/s

extend IPAC'10 study of
M. Giovannozzi, A. Xagkoni, F. Zimmermann:
varying initial position, second crossing, …

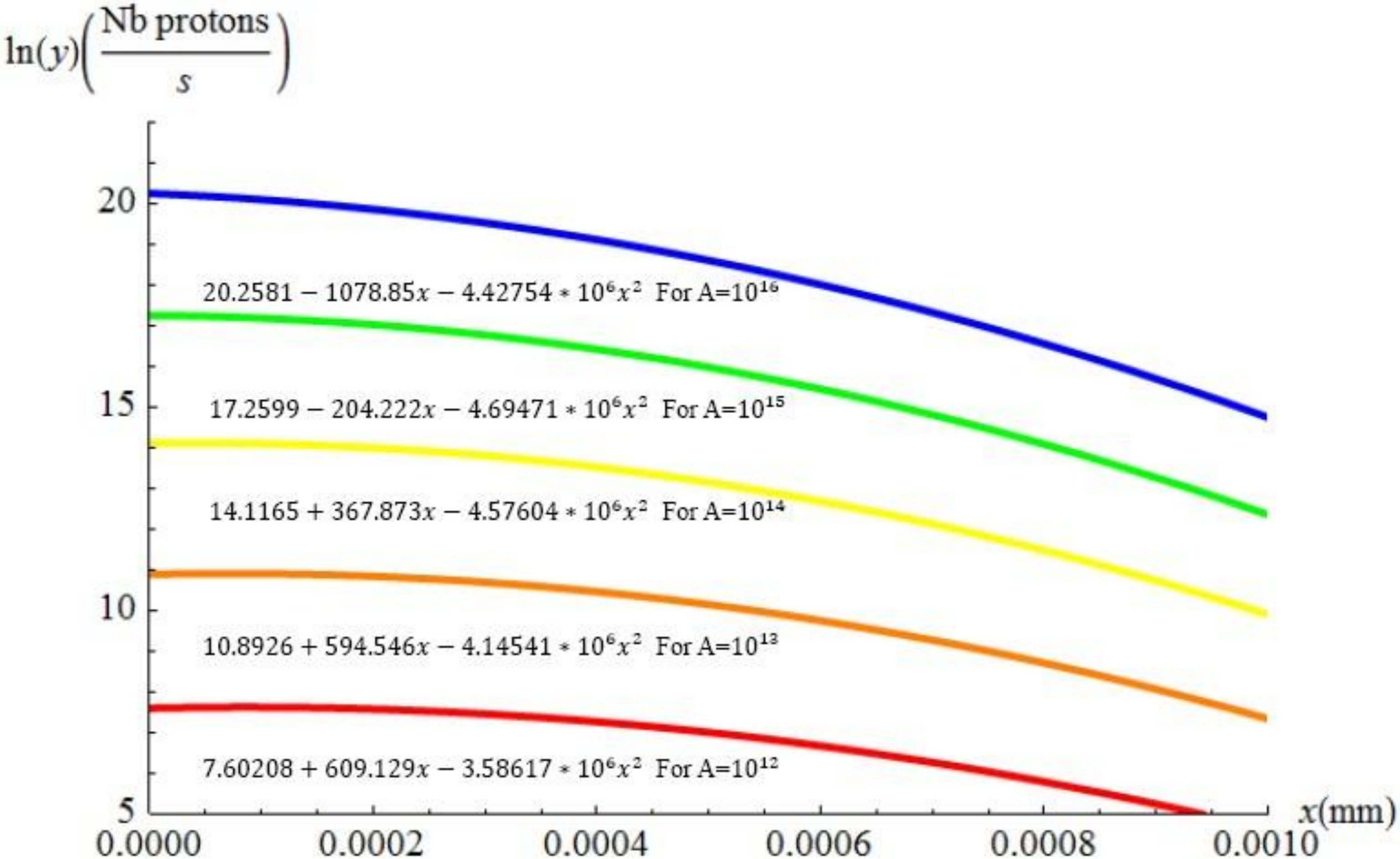
table with beam & particle parameters

Acceleration from Gravity	g=9.81m/s^2
Radius of the vacuum chamber	b=0.02m
Circumference of the storage ring	C=26700m
Total number of protons in the beam(protons/beam)	nprotons= 0.9*10^11*25
crossection	0.42*10^(-28) m^2
rms beam size	σ=0.0003m

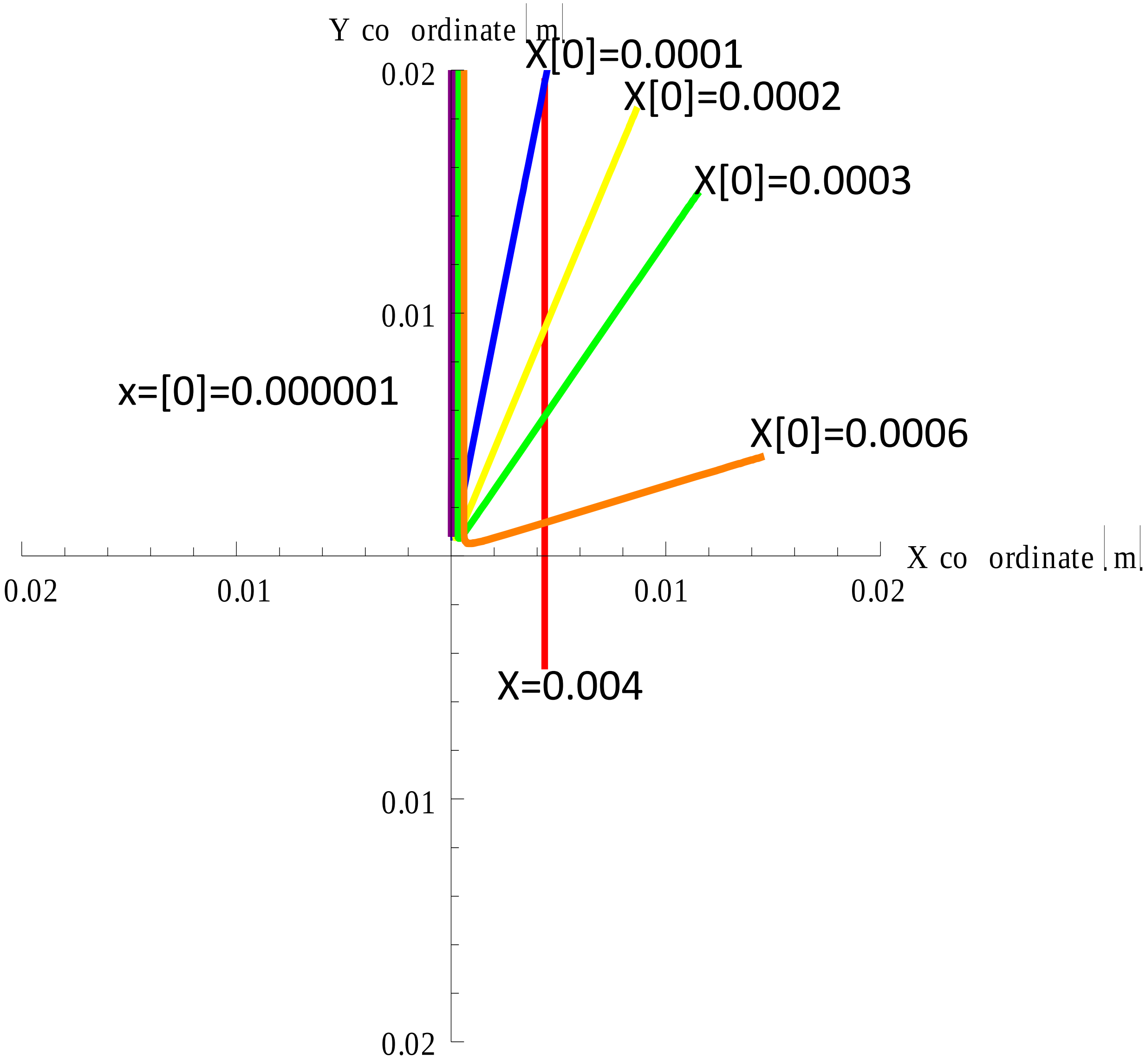
Resulting loss rate with different x[0] and different mass



We can measure the maximum of each beam lost rate, and fit them by x co-ordinate with function ln y = a + b x + c x^2

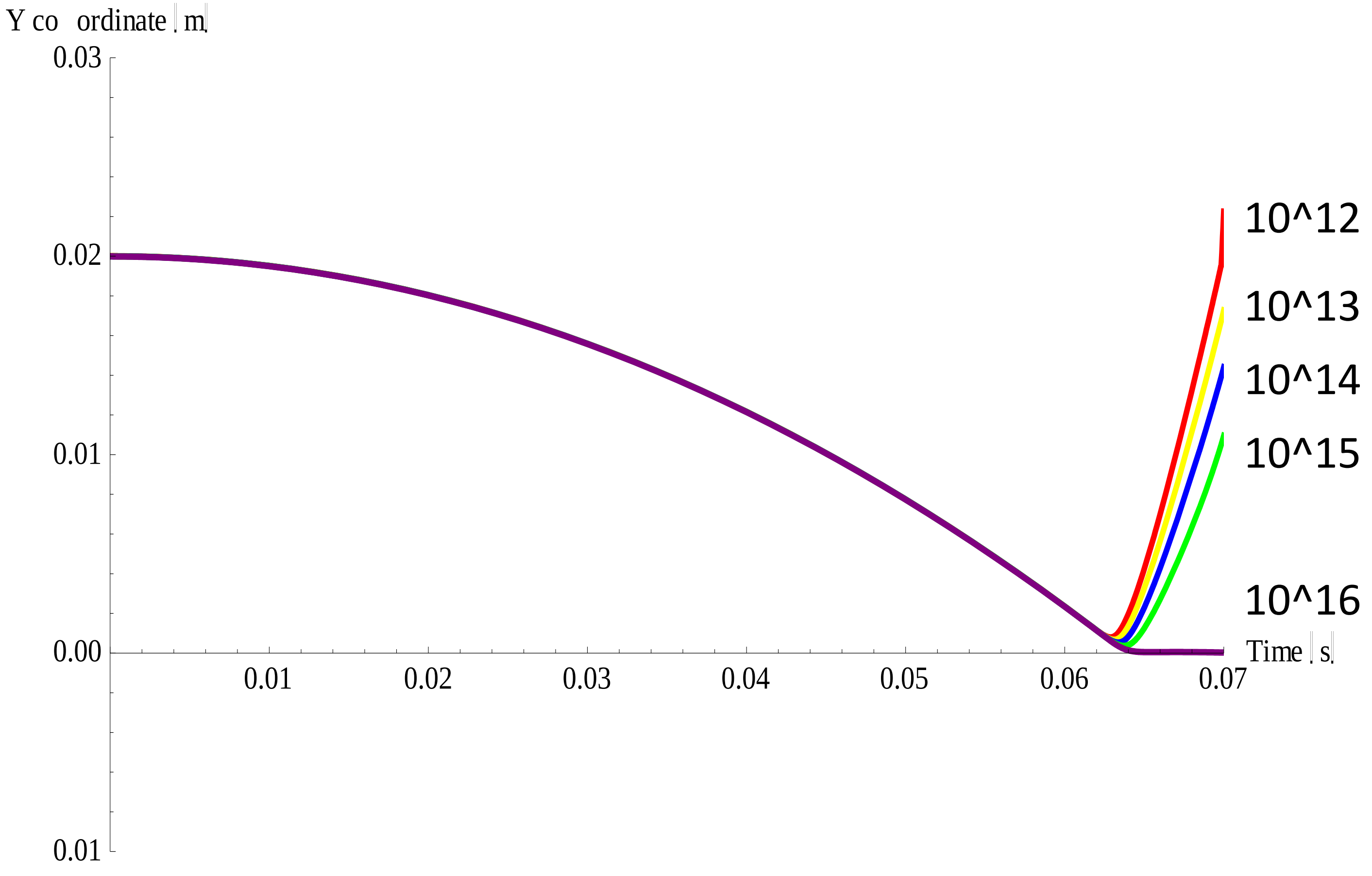


this is the plot with peak loss for different masses with x[0]=0.0001 m



When the particle crosses the beam, it may move upwards or fall down, this depends on the value of x.

If x is very small, it will fall down, otherwise move upwards.



Purpose: continue the calculation of particle motion and beam loss for a longer time to see the time interval at which they cross the beam the second time

To do this, we will need to extend the equations of motion:

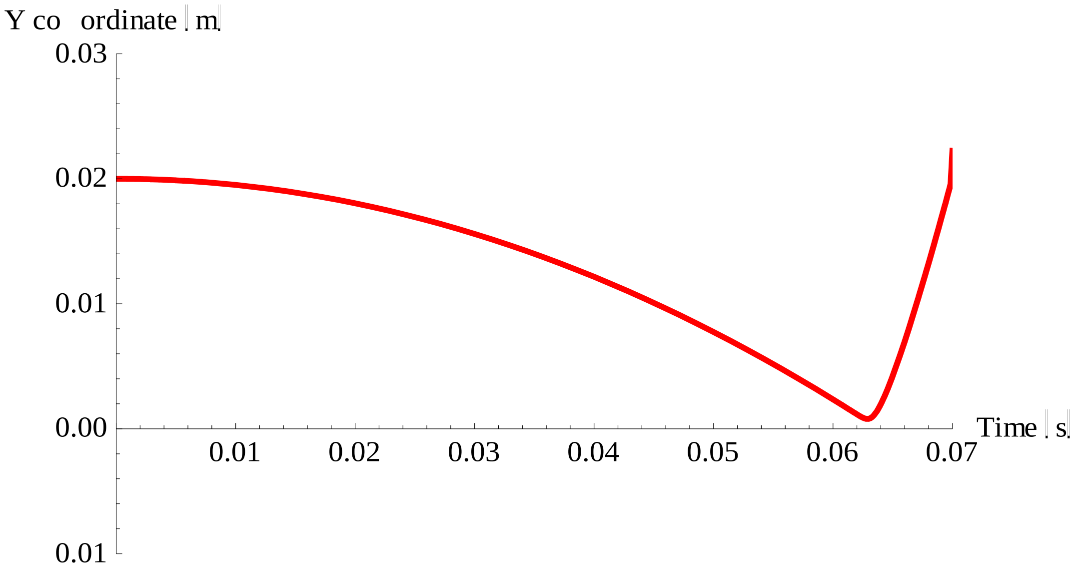
1) For those particles which fall down we do not need to do anything special.

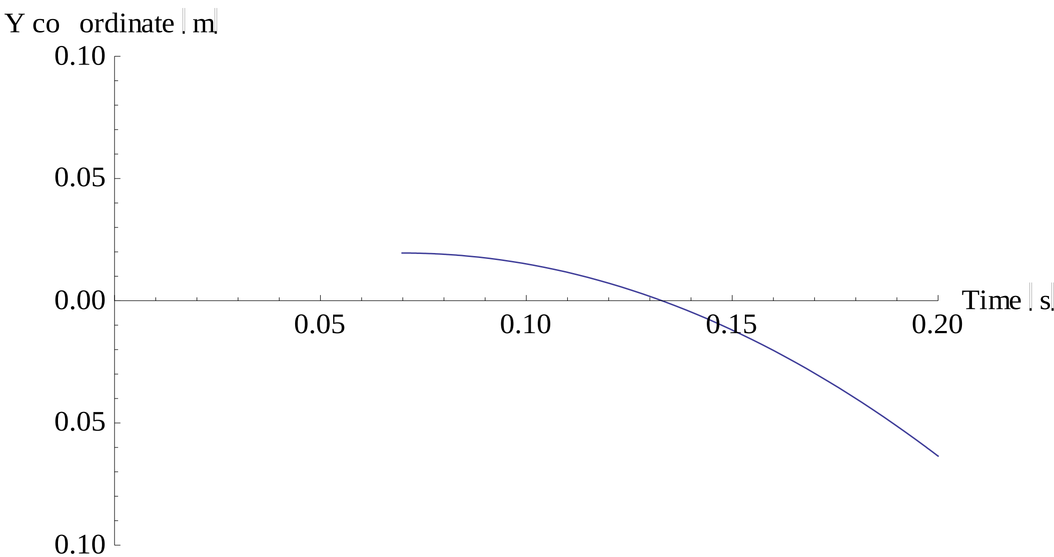
2) But for those particles which are repelled and move upwards, we should check if their y value exceeds the height of the chamber

when this happens we can reset their charge Q to -1,set the vertical velocity to 0, and set them back onto a distance equal to the chamber radius.

Q[t]=-1 x'[t]=0 y'[t]=0

This is an example for it: A=10^12; x[0]=0.0001





The point at which

y[t]=sqrt ((b-R[A])^2-x[t]^2)

is t= 0.0698373

Then we set:

y’[0.0698373]= 0

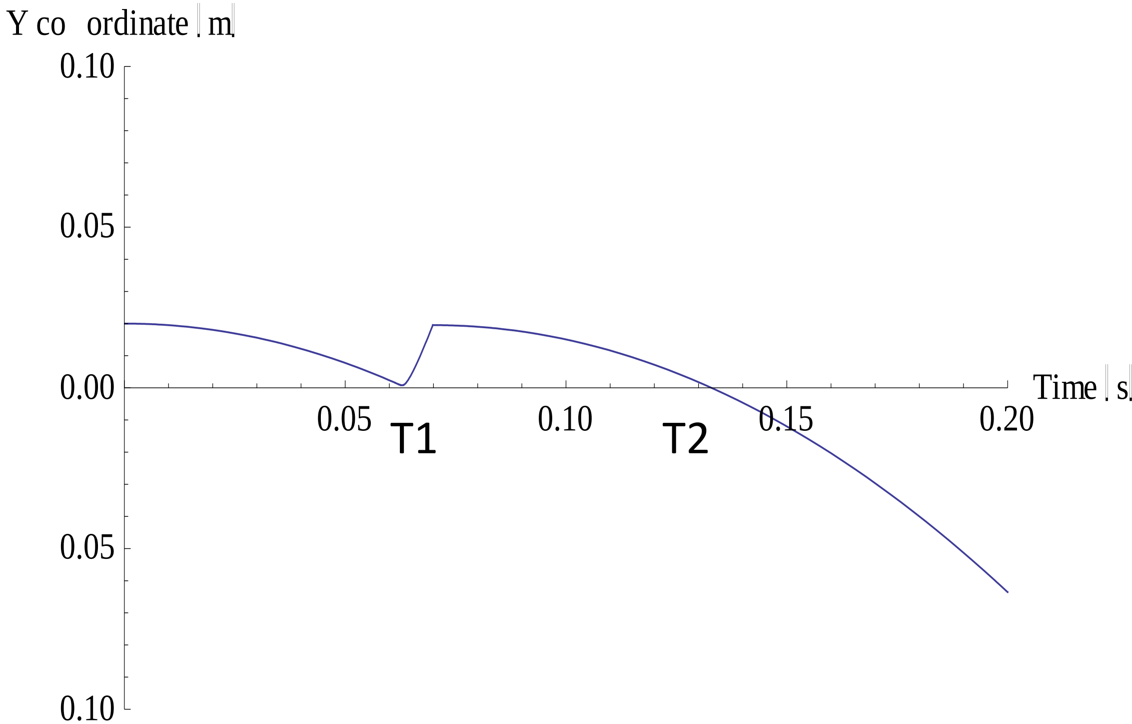
x’[0.0698373]= 0

Q[0.0698373]= -1

And we can get a new curve

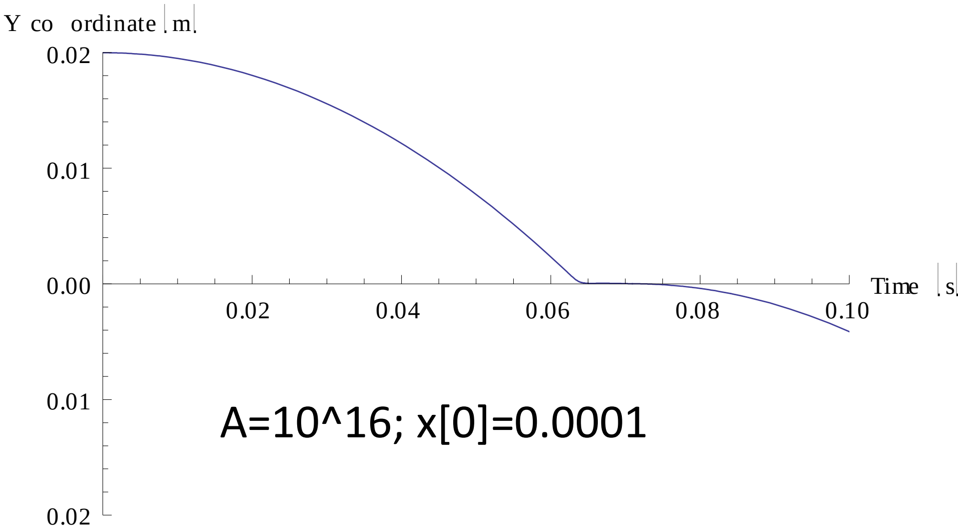
for {t, 0.0698373,0.02}

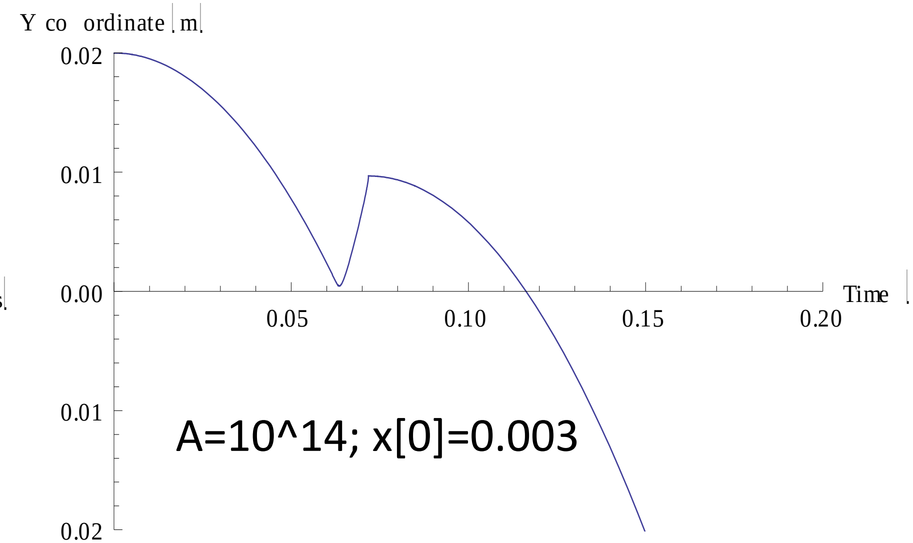
Combining those two curves, we can get the curve which shows the particles cross the beam the second time :

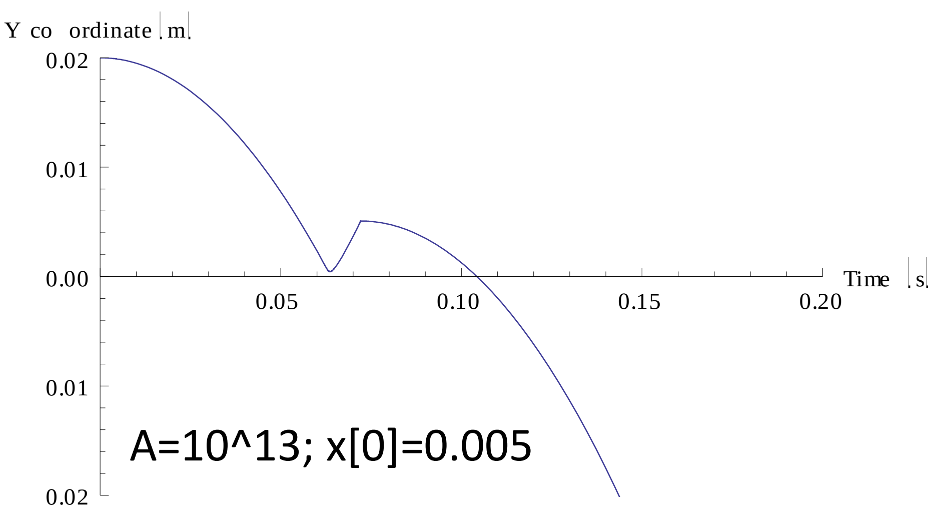


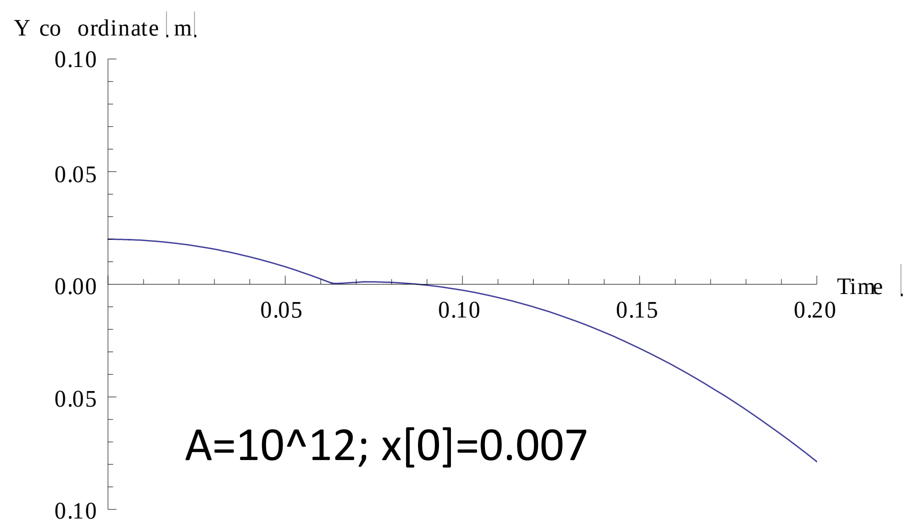
T1= 0.0628688
T2= 0.132933
⊿T= 0.0700643

Some other examples with different conditions





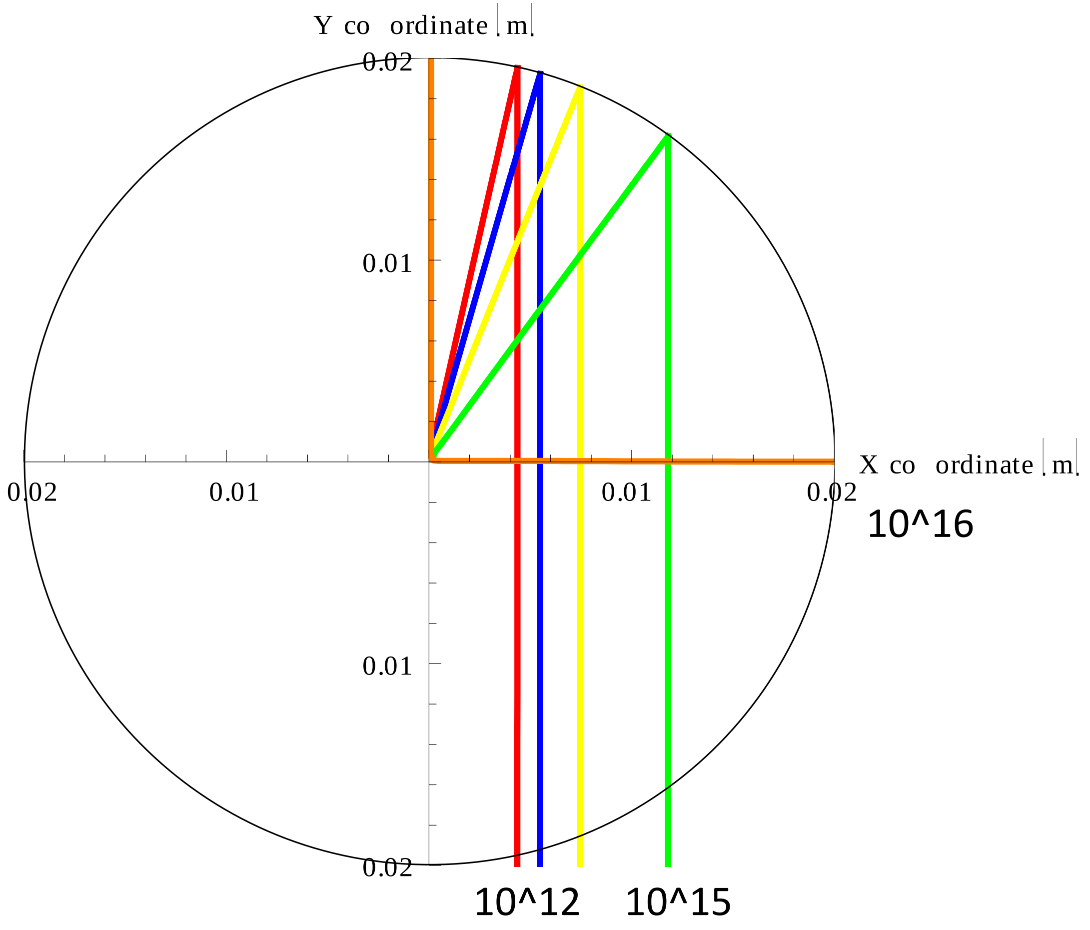




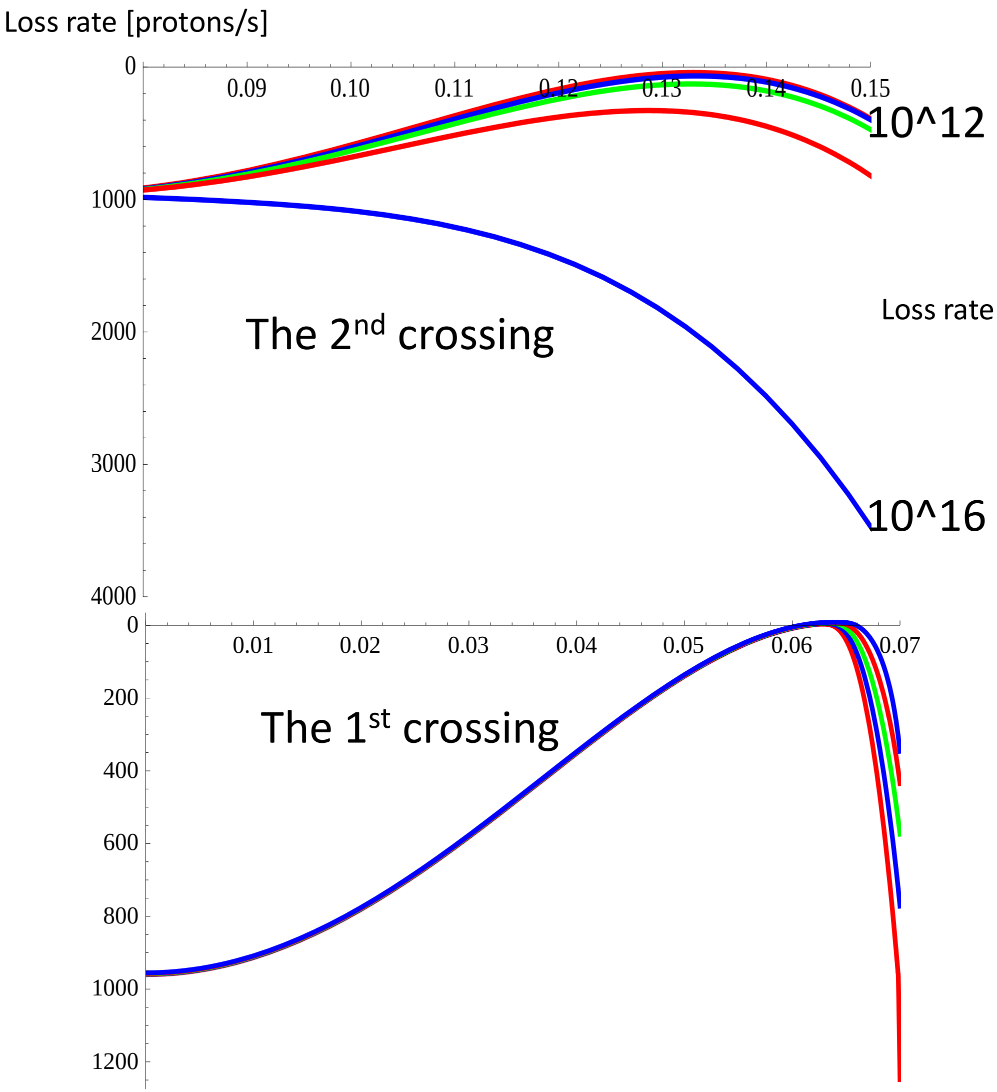
the table of ⊿T with different mass and different x[0]

x=0. 0001					
A	10ˆ12	10ˆ13	10ˆ14	10ˆ15	10ˆ16
t (s)	0. 070064	0. 0701	0. 682928	0. 0649	0. 001548
x=0. 0003					
A	10ˆ12	10ˆ13	10ˆ14	10ˆ15	
t	0. 064052	0. 060711	0. 052688	0. 007779	
x=0. 0005					
A	10ˆ12	10ˆ13			
t	0. 051286	0. 040636			
x=0. 0007					
A	10ˆ12				
t	0. 023107				

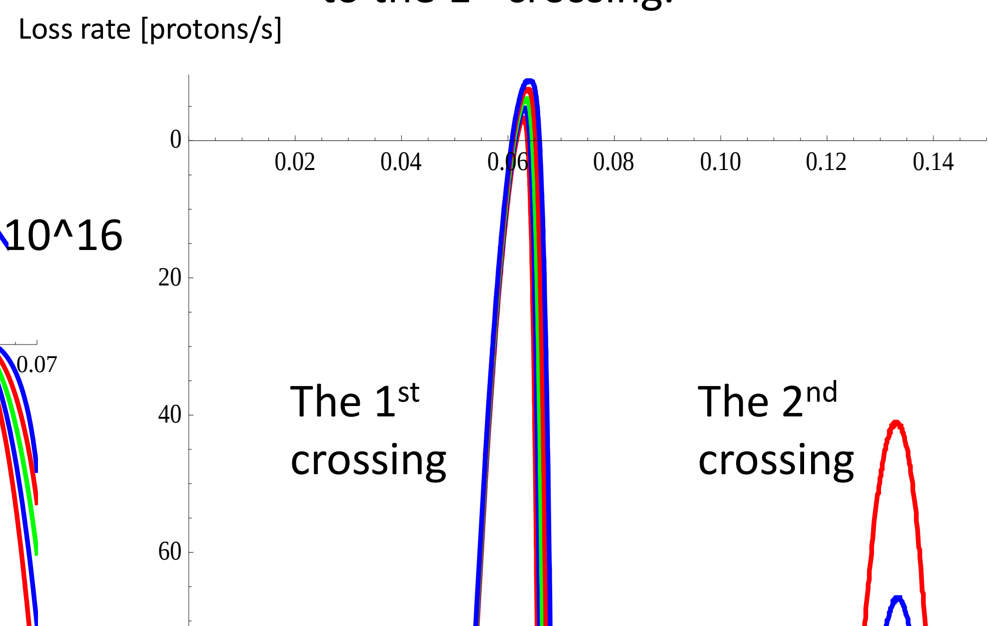
This is the trajectory in x-y space for A=10^12 to 10^15, the particles are charging up to be repelled upwards for the 1st time and all of them are falling down for the 2nd time.



plot with beam loss for 1st and 2nd crossing with x[0]=0.0001m



The beam loss rate of the 2nd crossing is quite small comparing to the 1st crossing.



plan for future work

- complete project report
- repeat calculations for higher beam current
- vary beam size (injection)
- introduce magnetic field
- look at other shapes and materials (plastic)
- make mathematica notebooks more automatic