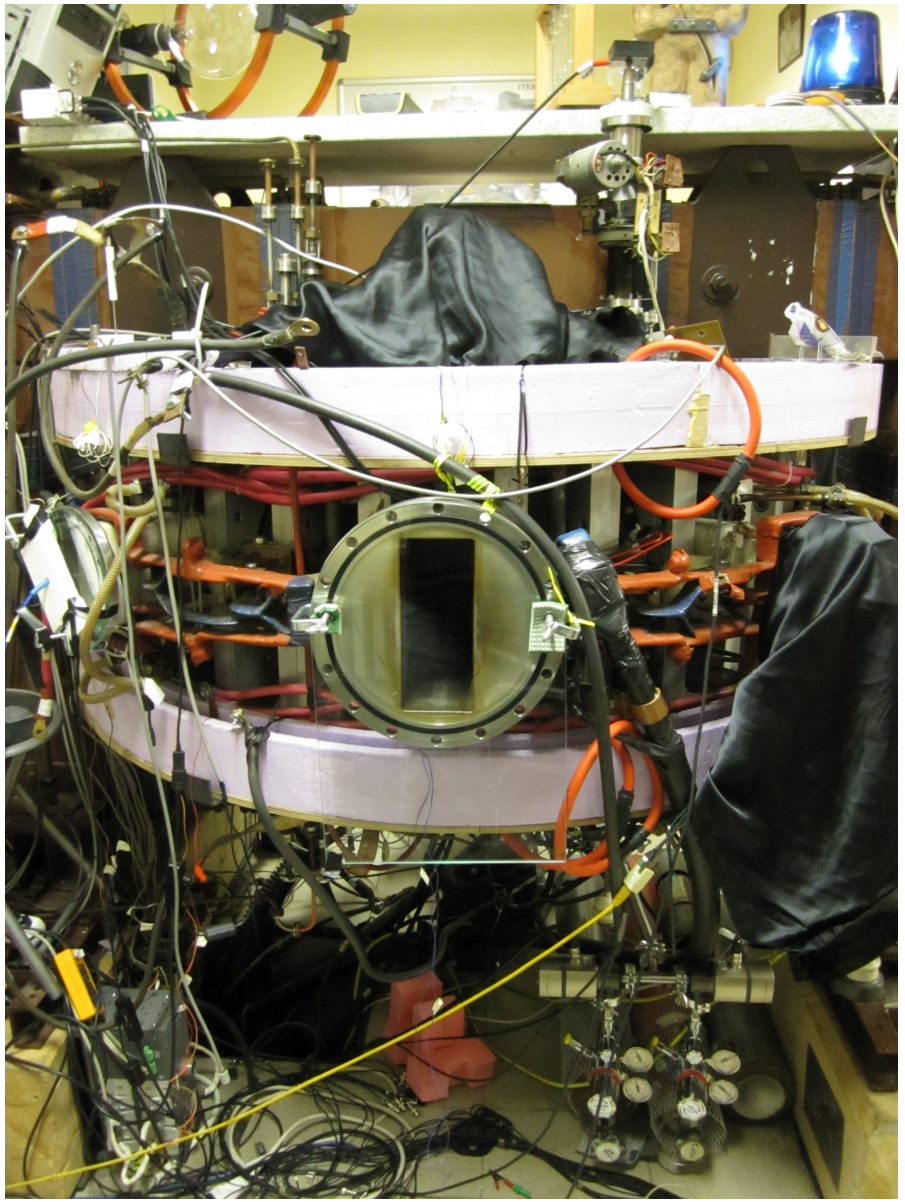
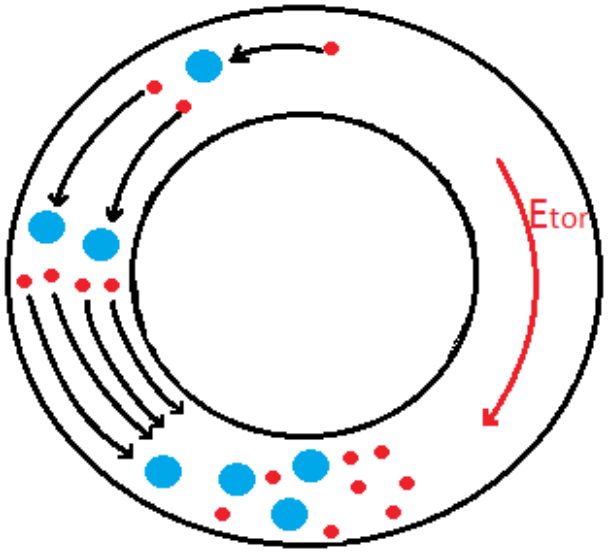
Golem : Breakdown studies



- 28 toroidal field coils, creating the toroidal magnetic field. (powered by capacitor bank)
- Transformer with iron core and 24 primary winding turns, producing the toroidal electric field.
  (powered by capacitor bank)
- 18 diagnostic ports (including a fast camera, a spectrometer, a photodiode...)

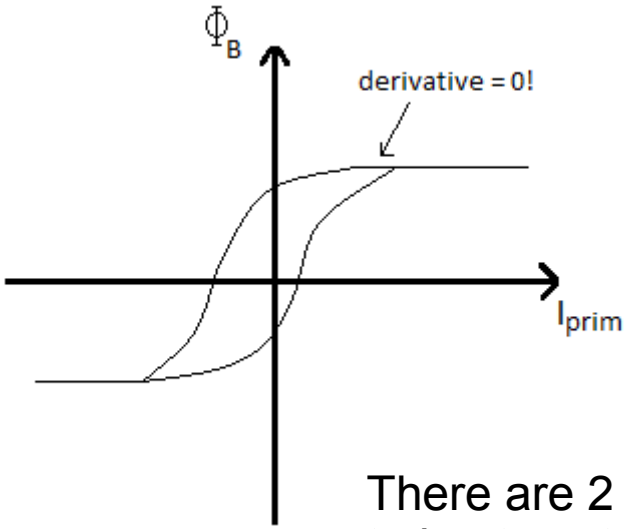
Motivation for breakdown optimization

In order to have a plasma, there needs to be a breakdown : an ionization in cascade induced by the toroidal electric field.



The toroidal electric field is induced by the variation of the magnetic flux in the center of the torus.

This magnetic flux is however limited by the fact that it is going through an iron core, thus describing a saturated hysteresis.

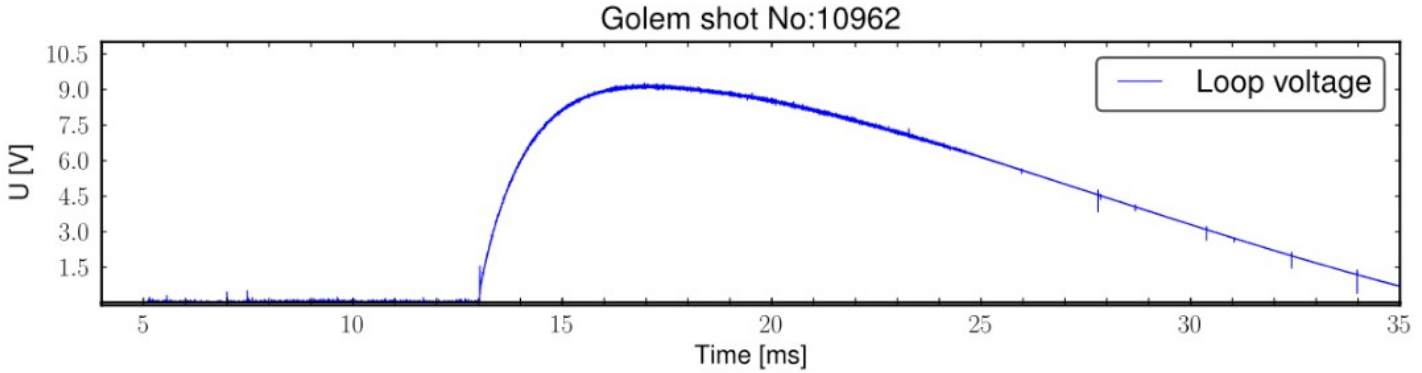


$$E_{tor} \sim \frac{d\,\phi_B}{dt} = \frac{d\,\phi_B}{dI_{primary}} \frac{dI_{primary}}{dt}$$

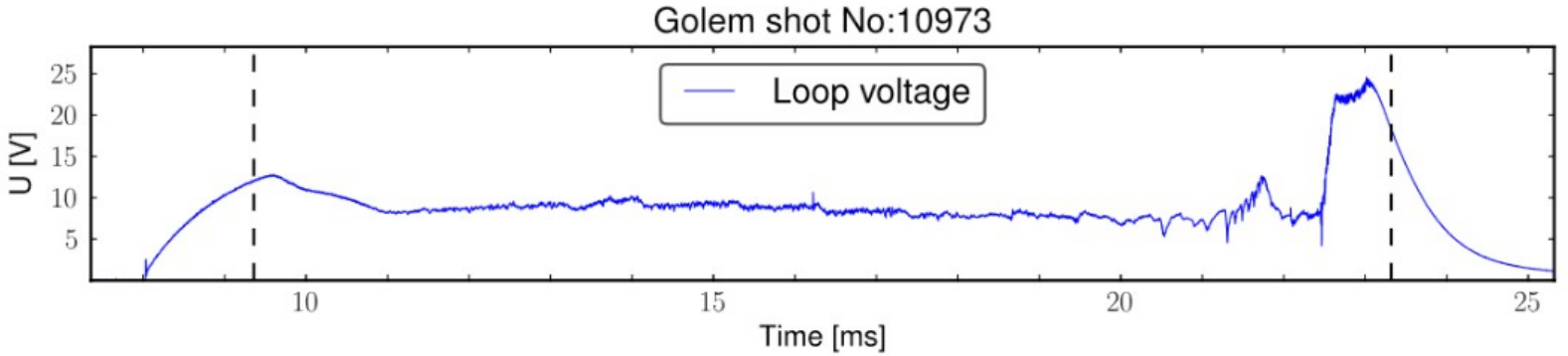
There are 2 problems encoutered when trying to extend the plasma current duration :

- $I_{primary}$ connot increase indefinetly.
- There is a saturation of the transformer.

Characterization of breakdown



No Breakdown : There is only current in the vessel.



Breakdown : After some time, the loop voltage decreases, indicating that the resistivity decreases : the gas becomes a plasma, and carries a current.

Because of the transformer saturation, the total time integral of the loop voltage is limited to about 0.12 V.s. The breakdown voltage must be as low as possible in order to have as long a plasma discharge as possible.

Optimization : parameters

We can modify 5 parameters on Golem :

- Charging voltage of capacitor bank for the toroidal magnetic field coils : U_B

- Charging voltage of capacitor bank for the central magnetic field, creating the toroidal electric field : U_{CD}

- Plasma pressure : P

- Time delay between the start of the toroidal magnetic field and the toroidal electric field : T_{CD}

- Preionization with an electron gun

U_B [v]	U_{CD} [v]	T_{CD} [us]	PreIon	P [mPa]	#	U_{Brd} [v]
1000	600	3000	Yes	20	10927	12.4
1000	400	3000	Yes	20	10935	9.8
1000	200	3000	Yes	20	10936	No plasma
1000	600	5000	Yes	20	10937	12.4
1000	600	1500	Yes	20	10938	12.2
1000	600	3000	No	20	10939	No plasma
1000	600	3000	Yes	14	10940	11.4
1000	600	3000	Yes	26	10974	12.8
1200	600	3000	Yes	20	10975	12.2
800	600	3000	Yes	20	10976	12.2

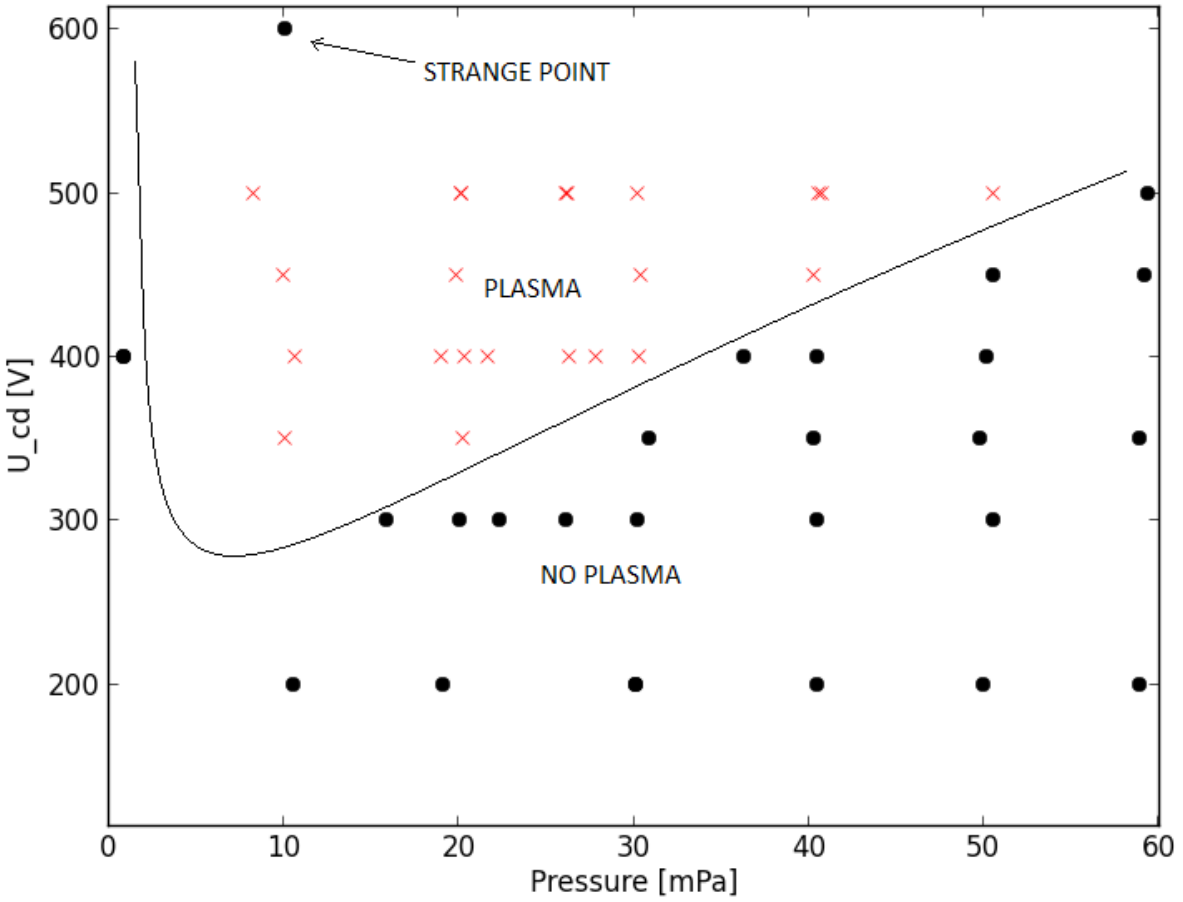
From this experiment, we can guess that the three most important parameters for breakdown voltage are the preionization, U_{loop}, and P.
It also seems that lowering P and U_{CD} decreases the breakdown voltage.

Main experiment

Multiple shots are done with only pressure and U_{CD} varying from one to the other. The preionization is set to be on, U_B is set to 700 V, T_{CD} is set to 8 ms.

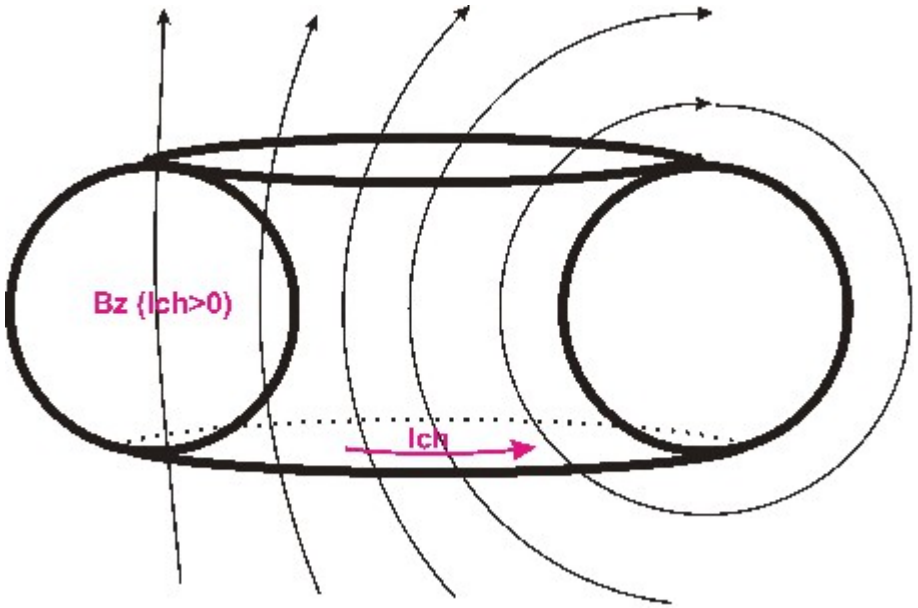
We plot the points for which there has or has not been a breakdown with the pressure on the x-axis and U_{loop} on the y-axis.

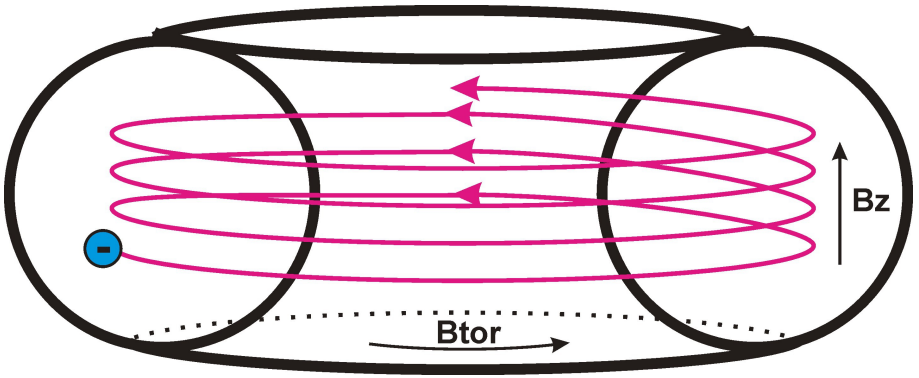
18 shots ordered, and additional shots from GOLEM database used.



Explanation for the strange point

The point corresponds to a shot with very high U_{CD} and therefore a high current in the vessel from the begining. This high current produces then a vertical magnetic field on the opposit side of the torus.





Free electrons will follow the magnetic field lines into the wall of the vessel, becoming then unable to start a cascade of ionization. This problem can be avoided by reducing the toroidal electric field, increasing the toroidal magnetic field, or increasing the pressure.

Suggestions for further studies :

a) Investigate our hypothesis that minimizing U_{CD} and P minimizes breakdown voltage.

b) Study the time before breakdown, which affects the number of voltseconds spent.