Possibilities for further optimizing the H^-/D^- RF source

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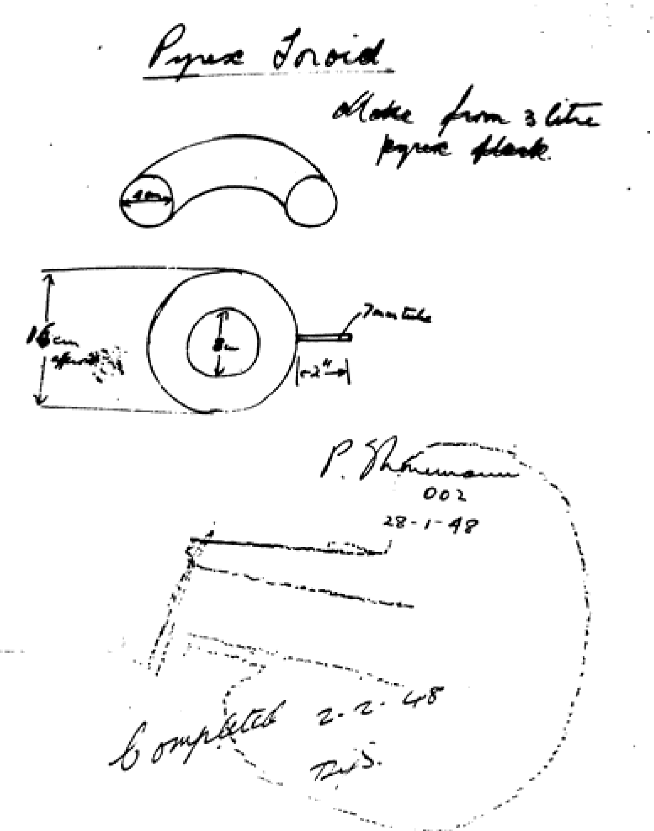
How fusion started

Drawing of the first UK torus built by P.C.Thoneman, an Australian sheep farmer with a farm the size of Holland who, as hobby, became a physics professor and had this device build in an Oxford laboratory in 1948.



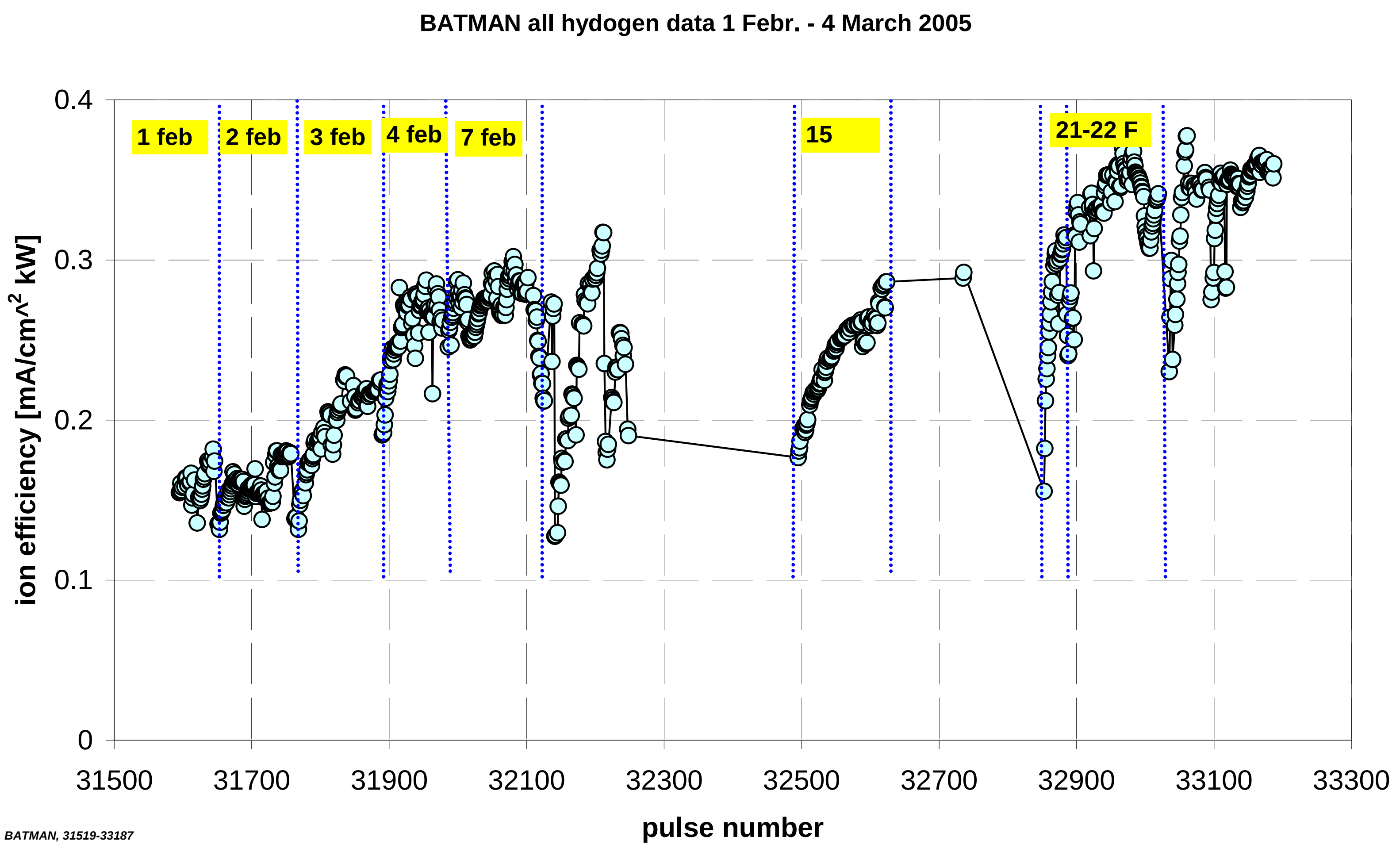
28-1 was a Wednesday, 2-2 a Monday, so it took 2 – 4 working days

http://www.fusione.enea.it/index.html#history/repertorio/reperto00.html

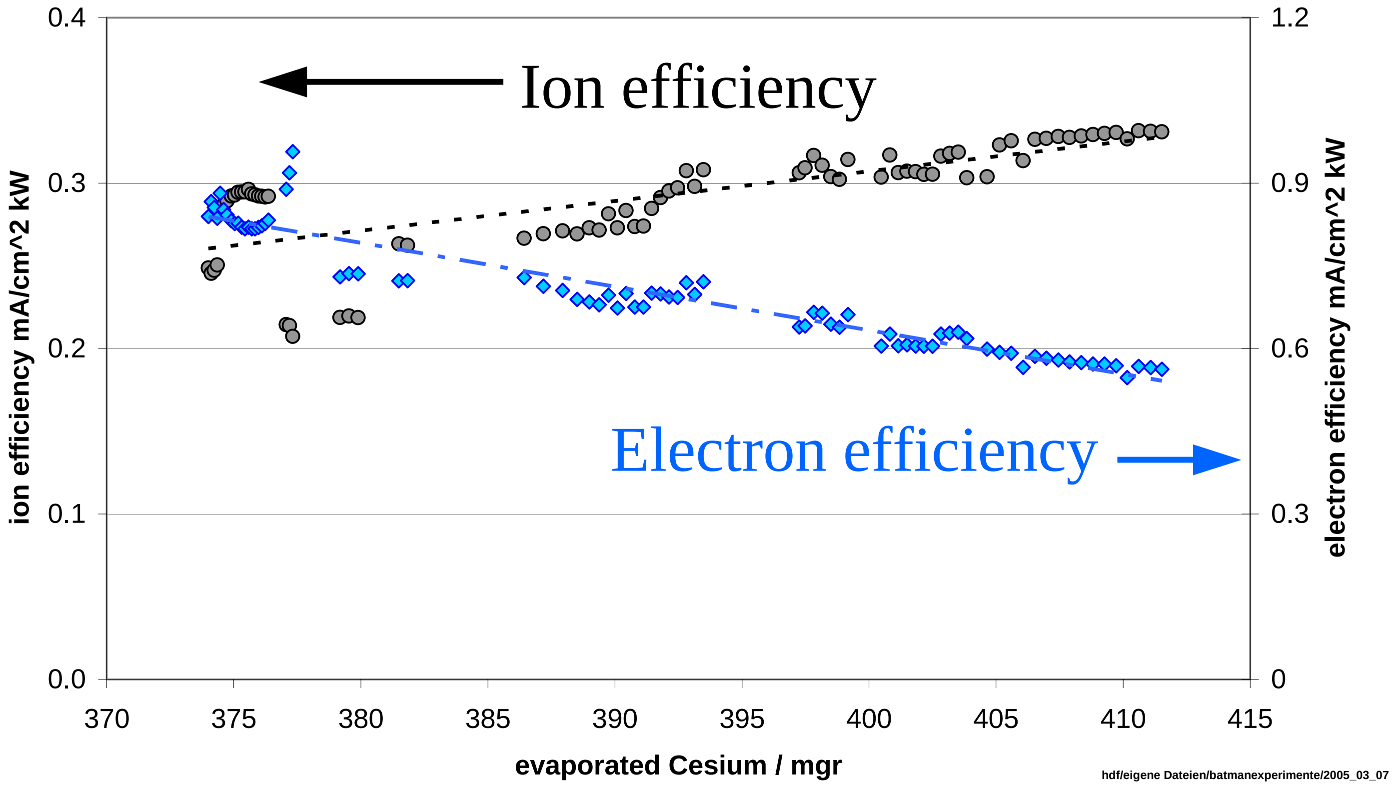
What’s required

- Ion source
- suitable Cesium coverage (rf source produces 4 – 5 mA/cm^2 without Cesium)
- patience – source appears to build up a good Cesium coverage provided one is not impatient
- Longer break with the source under vacuum seems to be beneficial – our best results so far always after the Christmas break

Source conditioning



Cesium



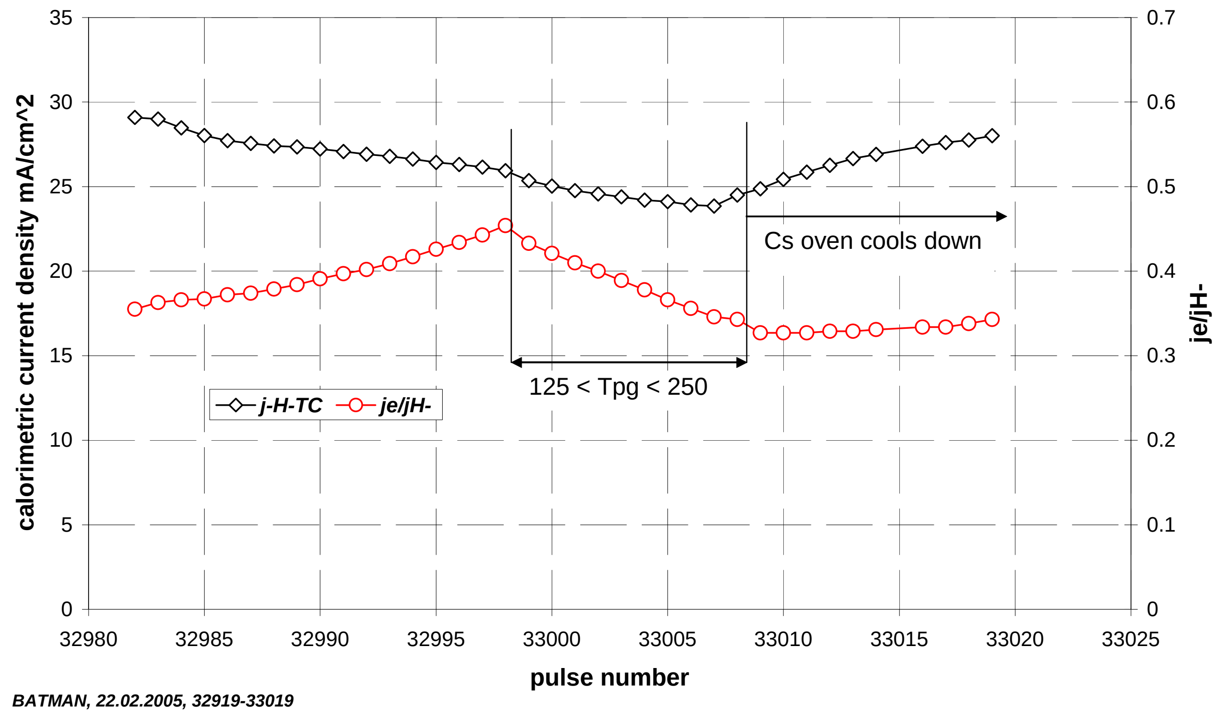
Example where Cs evaporation improves ion efficiency and reduces electron efficiency

Cesium 2

Example where ion current falls, electron to ion ratio increases at constant parameters and modest Cs evaporation of 0.5 mgr/pulse.

Increasing the PG temperature reduces the ion current density and the electron to ion ratio.

Turning the Cs oven off increases the ion current density with a small increase in electron/ion ratio



Cesium, what can be done

- controlled Cs evaporation during plasma on time – possibly with feedback on ion current or Cs emission.
- Cesium accumulates on cold areas and can move within the source possibly through gravity into an area with increased removal rate

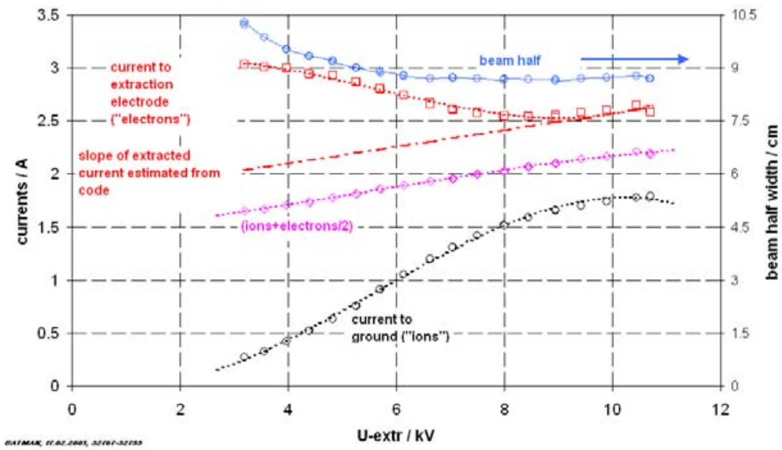
$\Rightarrow$ Control source temperature, provide Cs sump, fast acting dispenser

Fast acting control of PG temperature (cooling/heating loop).

Extraction voltage

Ion current increases with extraction voltage, electron current decreases, which is not likely when extracting from a plasma.

The sum of ions and electrons behaves roughly as one would expect the extracted current to behave



Likely explanation: at reducing extraction voltage an increasing fraction of the ions go to the extraction electrode.

The dashed line shows the extracted current from ray tracing model

The increase in beam width with reducing extraction voltage is insignificant (scraped beam)

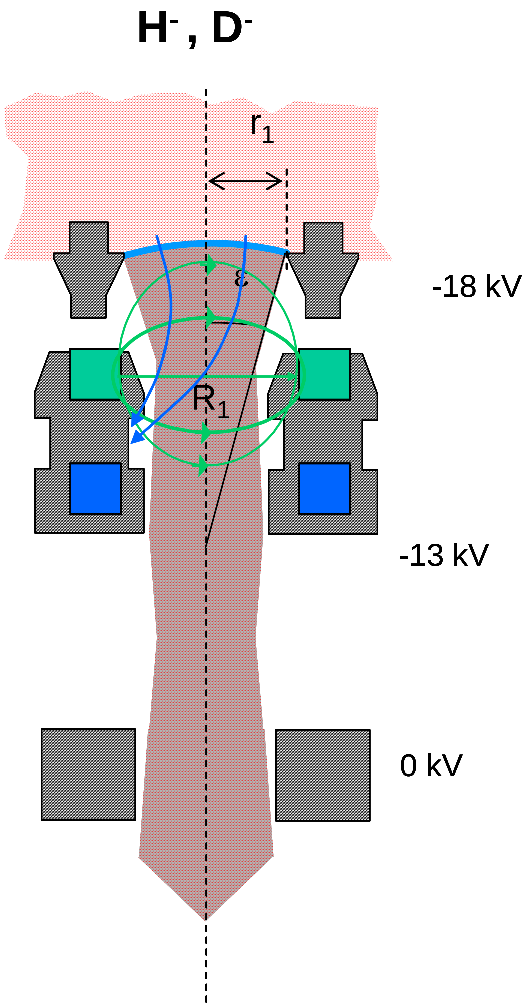
Extraction voltage

To extract sufficient negative ions sufficient extraction field is required

- beam converges initially, forms a narrow waist and blows up in the extraction electrode because of the low field there.

➢ a reduced height of the extraction electrode and a larger opening would improve beam optics

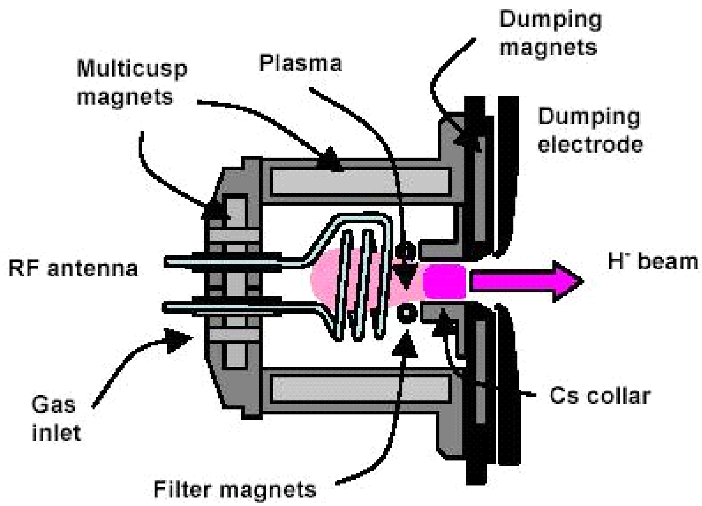
➢ With sufficient neg. ion density in the plasma lower extraction voltage and improved beam quality should become available.

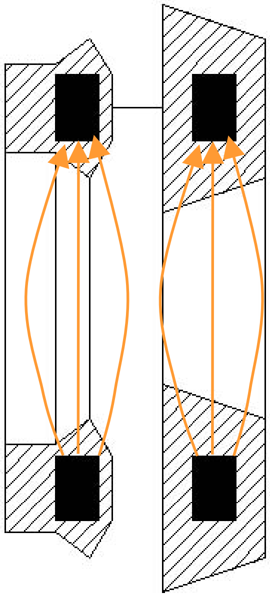


Electron deflection

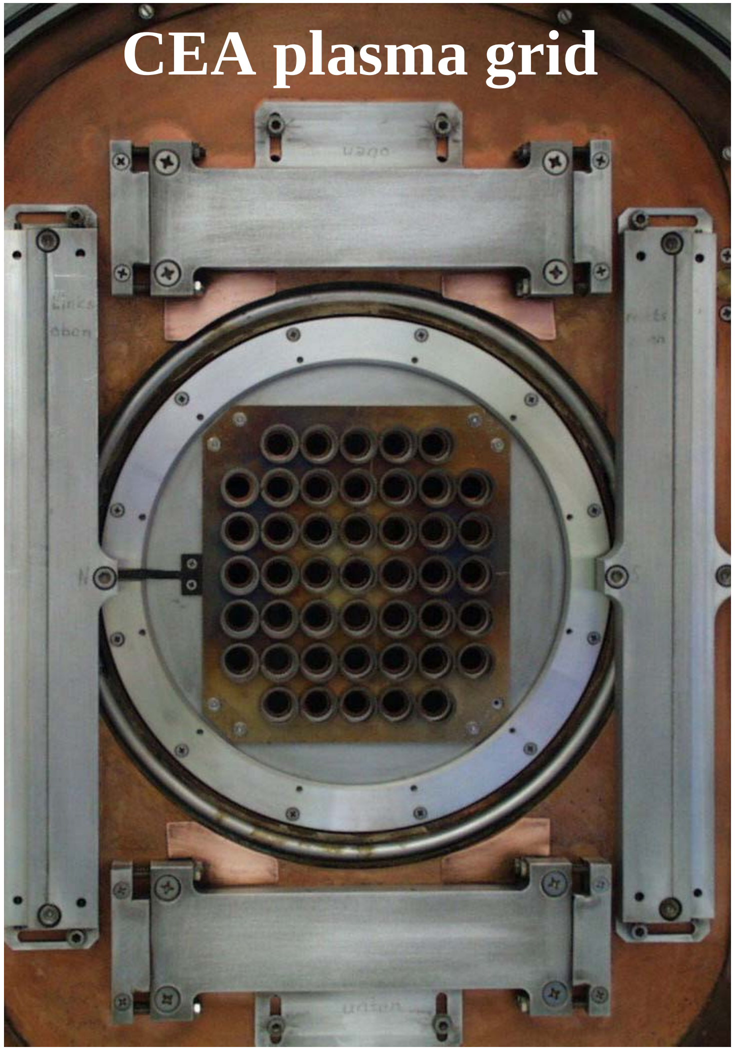
Plasma grid is likely to benefit from an increased surface – it should therefore allow to house some magnets – provided they tolerate the temperature.

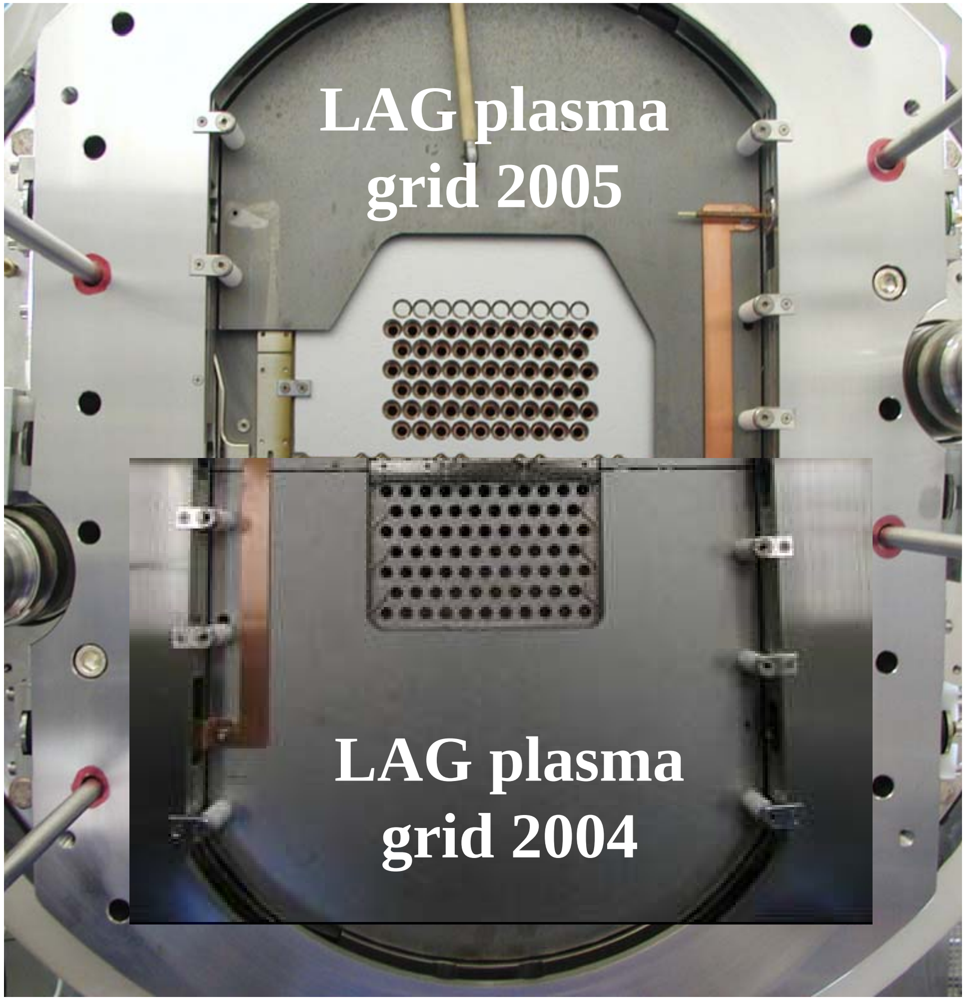
This would allow to reduce the height of the extraction electrode.



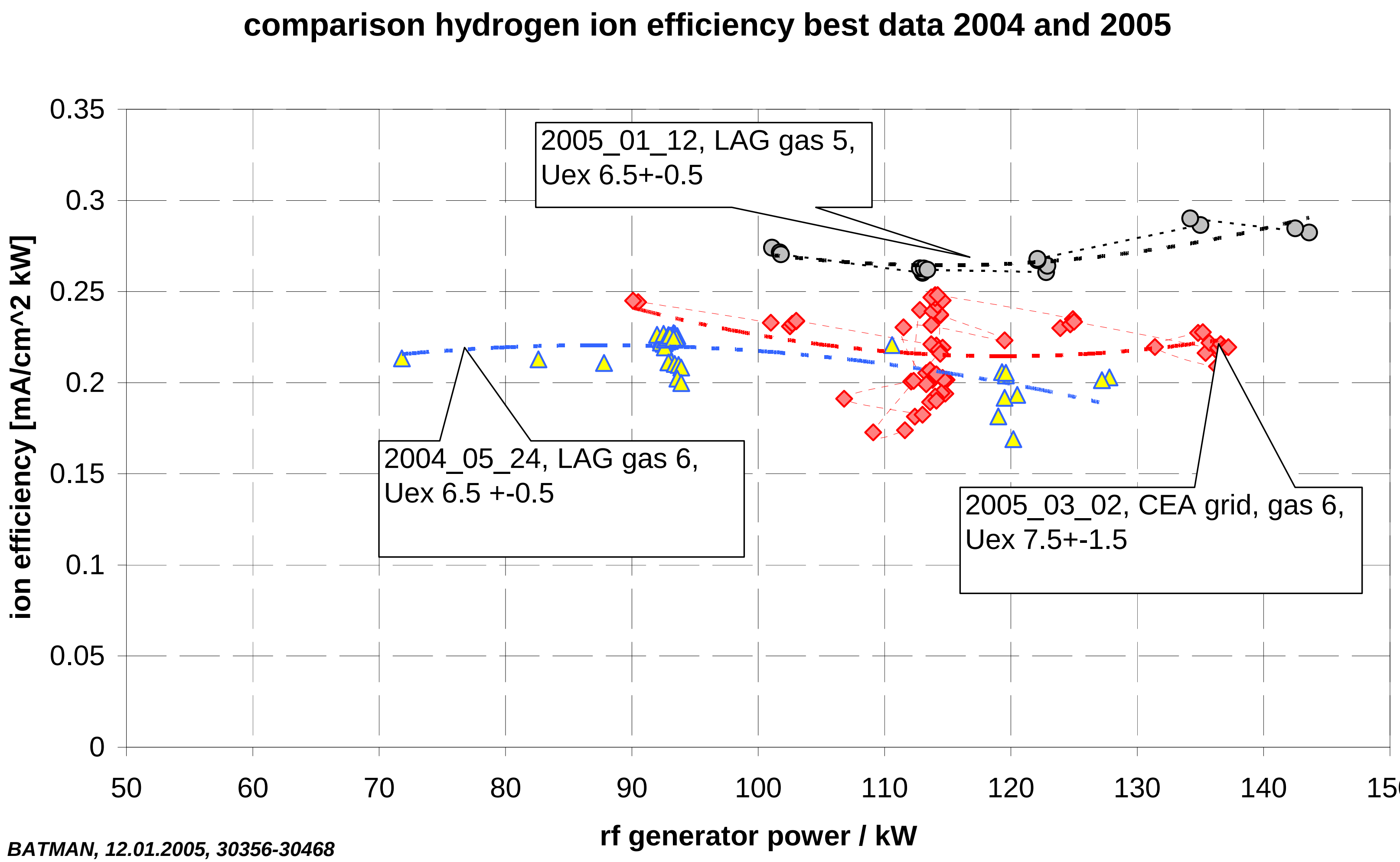


Plasma grid shape

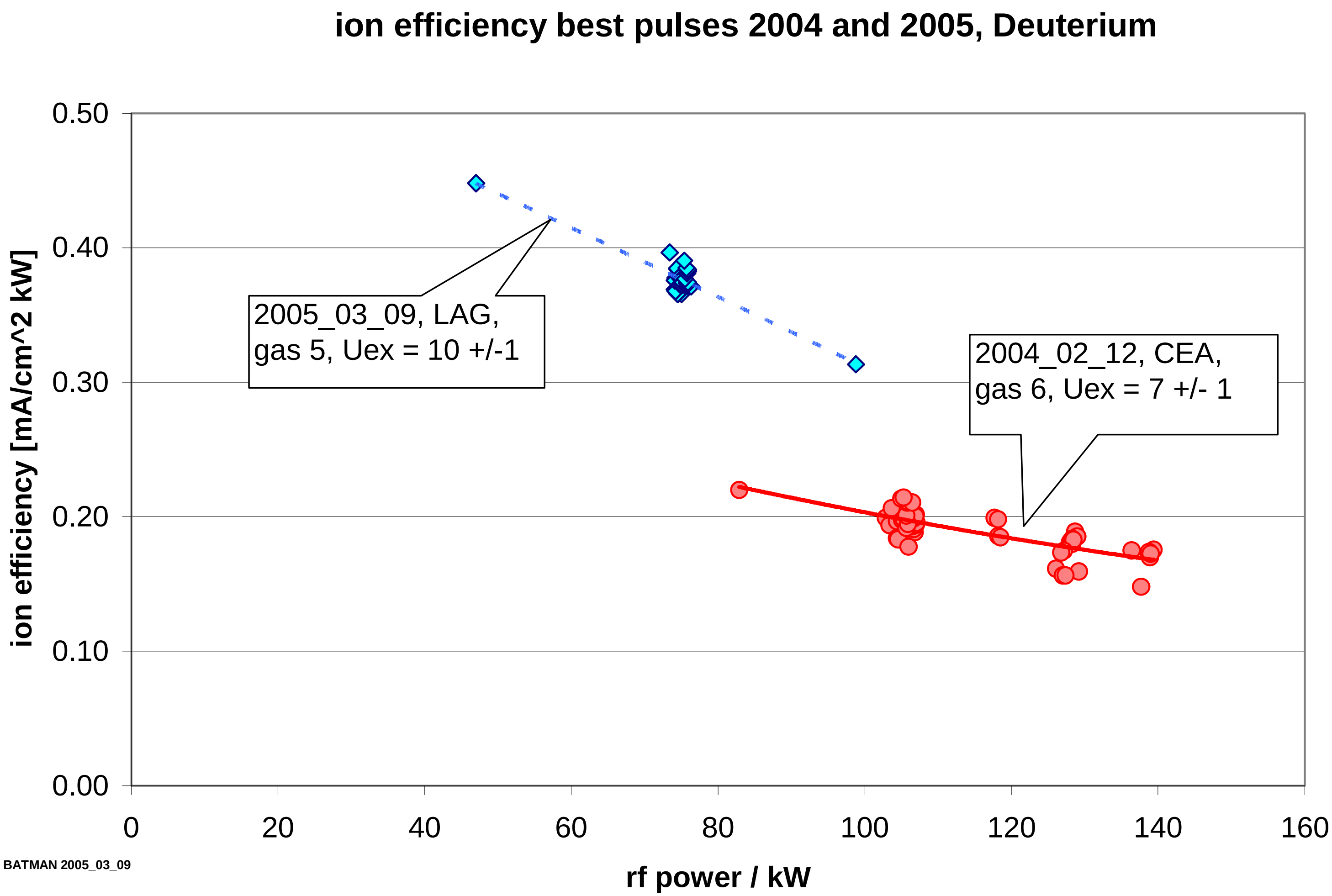




Plasma grid shape



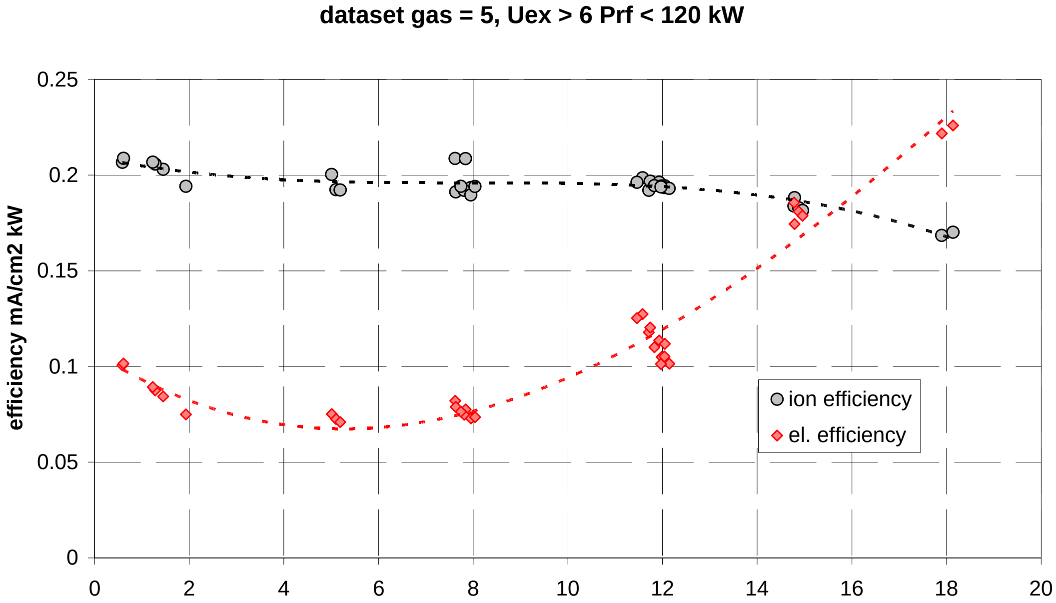
Source efficiency



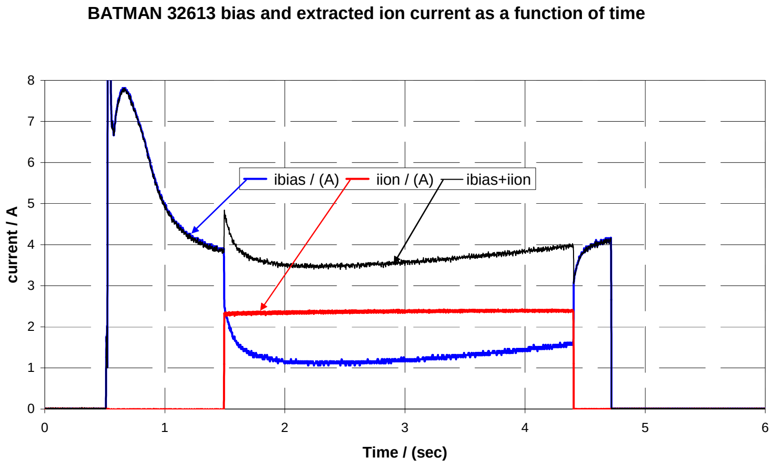
Bias Voltage

Badly or not cesiated source: increasing bias voltage **reduces** the electron current and **increases** the ion current. Well cesiated source: **the opposite**

Best results with bias currents near zero (floating plasma grid).



BATMAN, 06.12.2004, 29731-29852



Bias current falls with extraction by the level of the ion current.

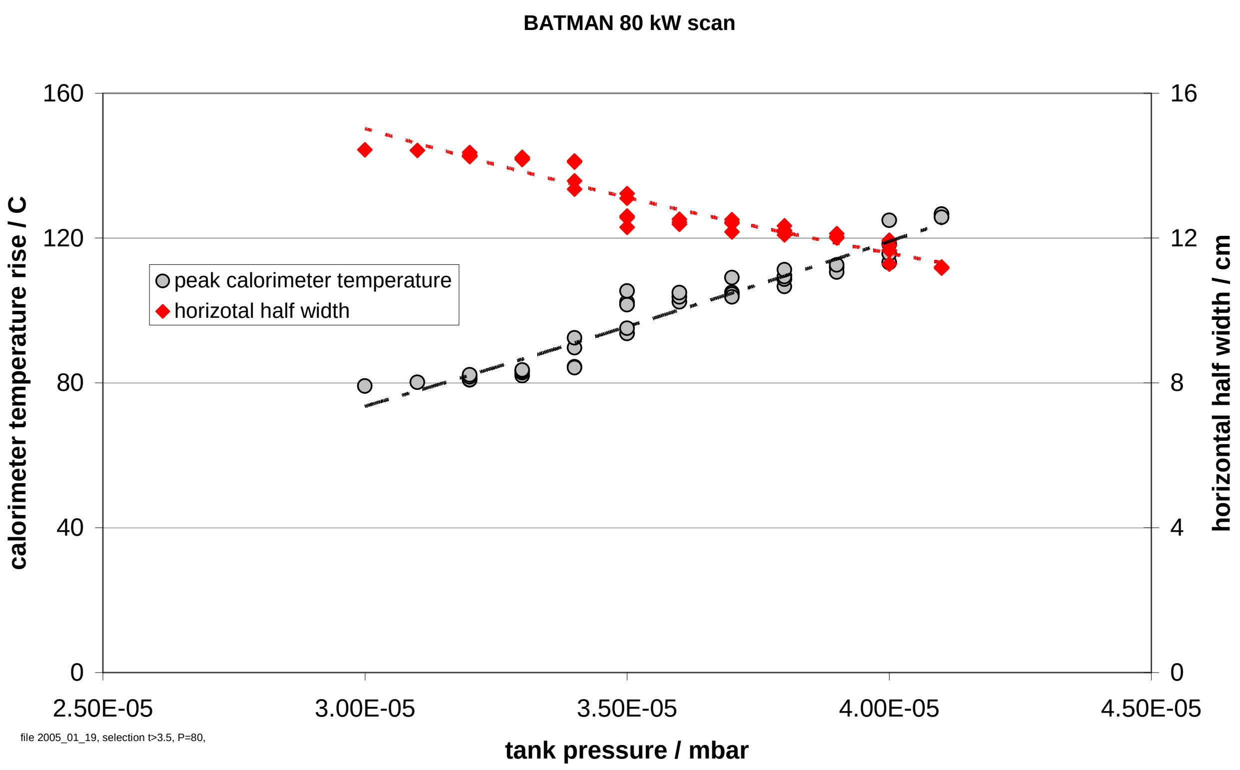
Explanation: few electrons?

Ion deflection

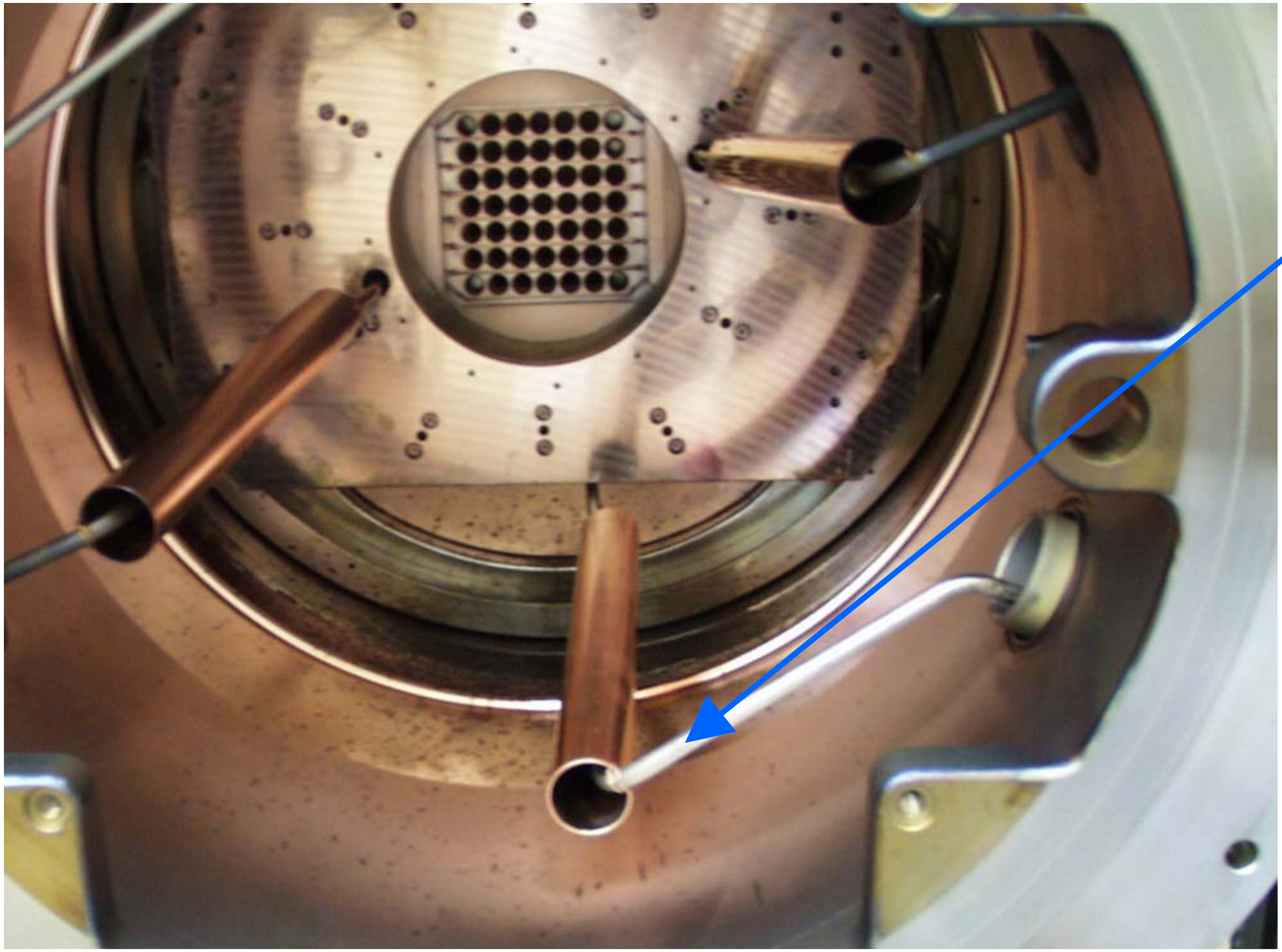
Visible beam blow-up with increasing pressure

Mean free path for electron detachment is roughly 2 m for 20 keV D^-

➢ Caution when comparing measured and calculated profiles



So-called “Argon” effect



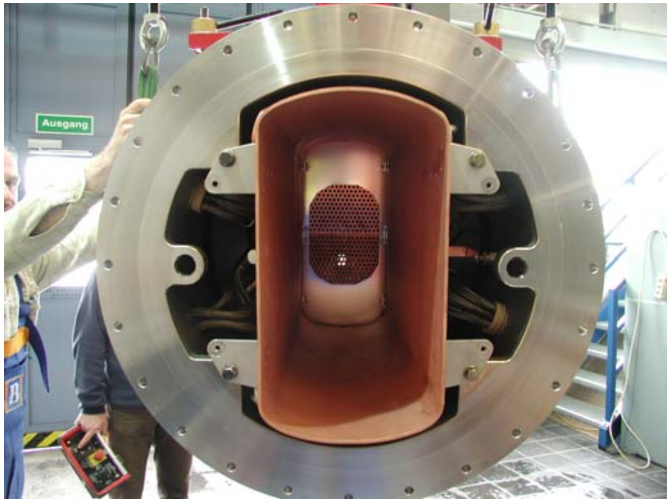
Electrical field from the water pipes of the extraction electrode deflected ions.

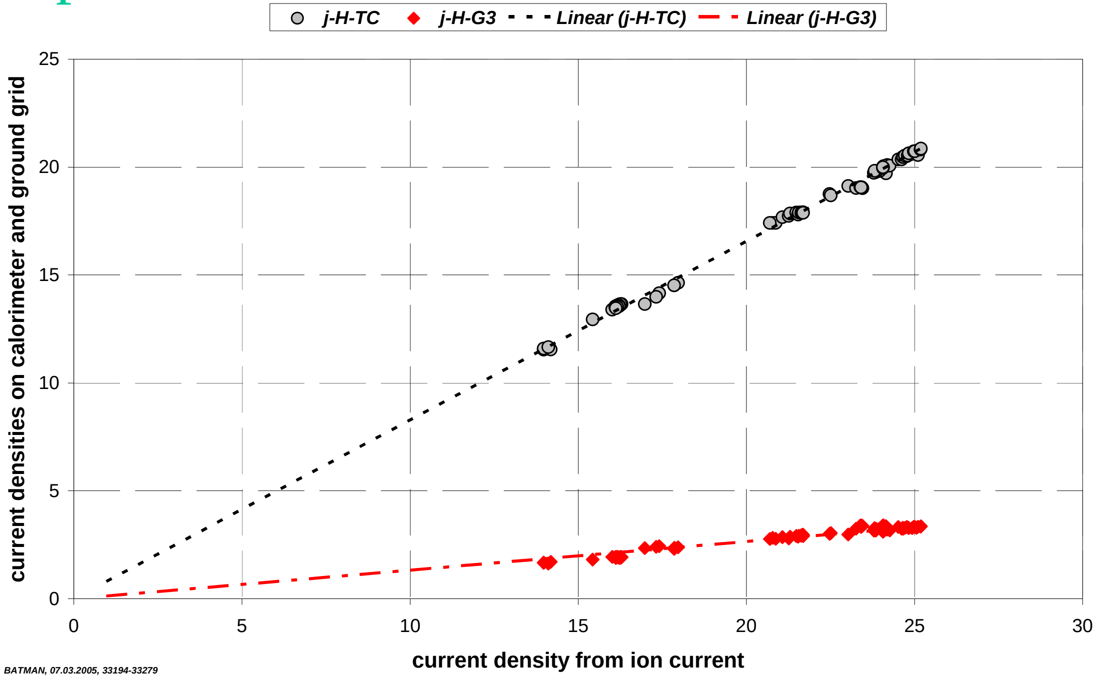
Addition of Argon increases neutralisation as Ar is not being pumped by the titanium getter pumps.

Using a neutraliser as electrical screen improves the accountability,

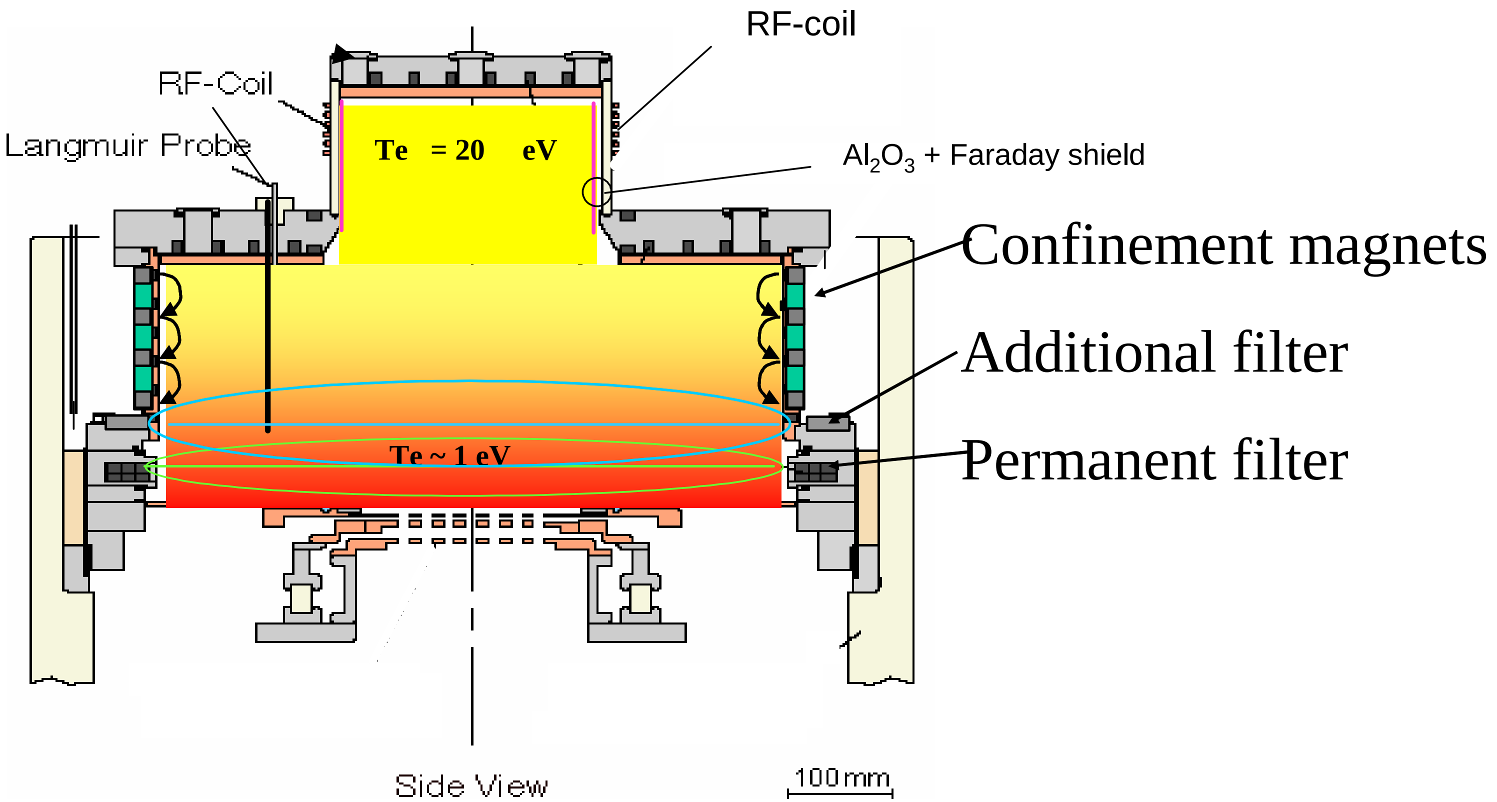
penalty are increased stripping losses

caused by higher pressure in the accelerator

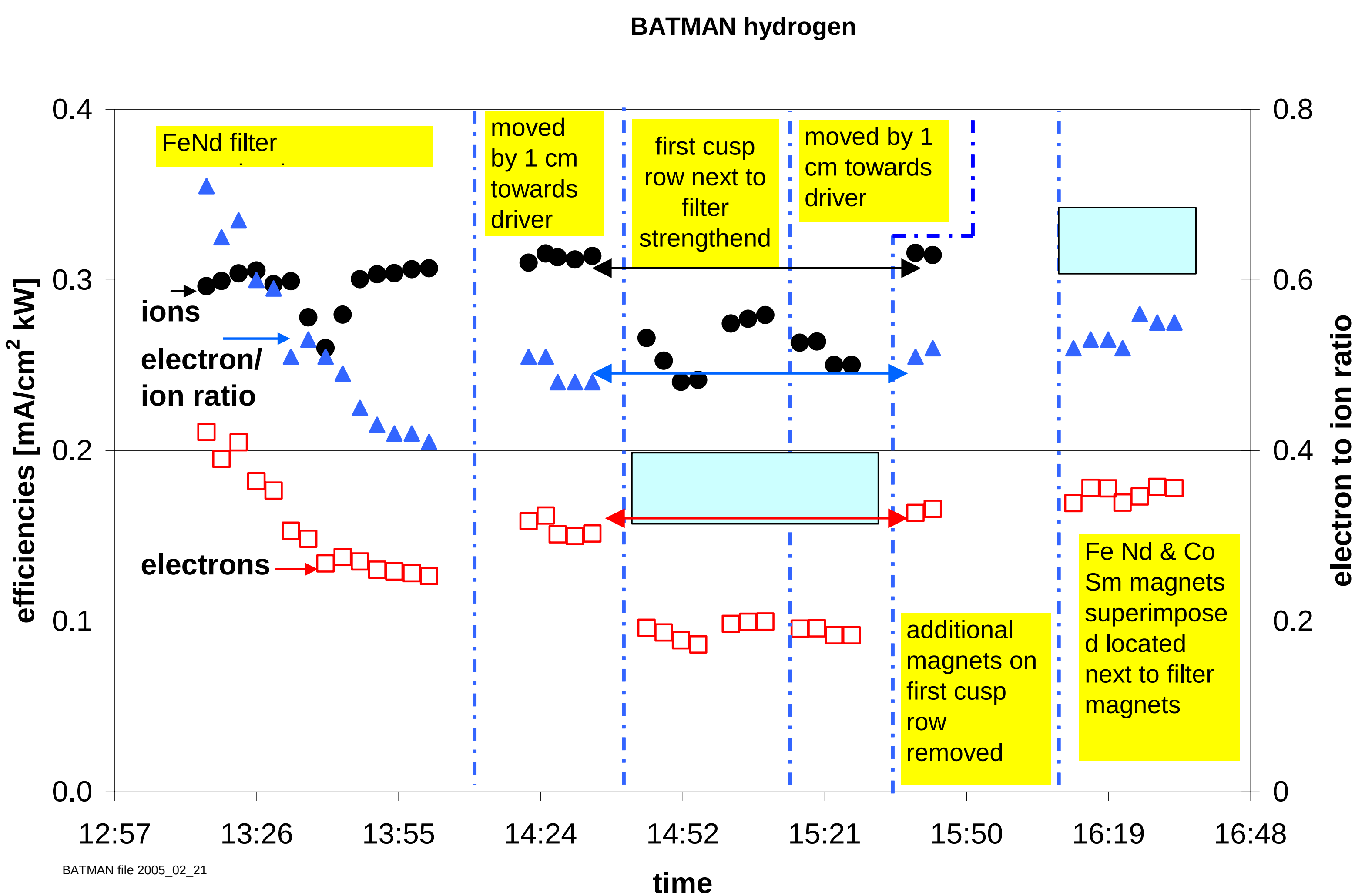




Filter field



Filter field and plasma confinement



Filter field and plasma confinement

- **Electron to ion ratio can be controlled through the filter field.**
- **Highest ion efficiency with strongest confinement field.**
- **Lowest electron to ion ratio with strongest filter field.**
- **Results could be misleading as the Cesium redistribution is also affected by the magnet configuration.**
- **With the present set-up it is difficult to reduce the electron to ion ratio below 1 for deuterium.**

Likely reason: the distance between the magnets is too large (320 mm, $\int B dl \approx 0.5$ mTesla m)

Conclusions

Control of Cesium distribution in the source is dominant.

- Tools: Control of rate of dispensing and wall temperature.

Reduced extraction voltage beneficial for beam optics.

- source should have reserve in negative ion density.

Shape of plasma electrode is likely to affect.

negative ion production rate.

Space charge blow-up in the drift space increases beam width.

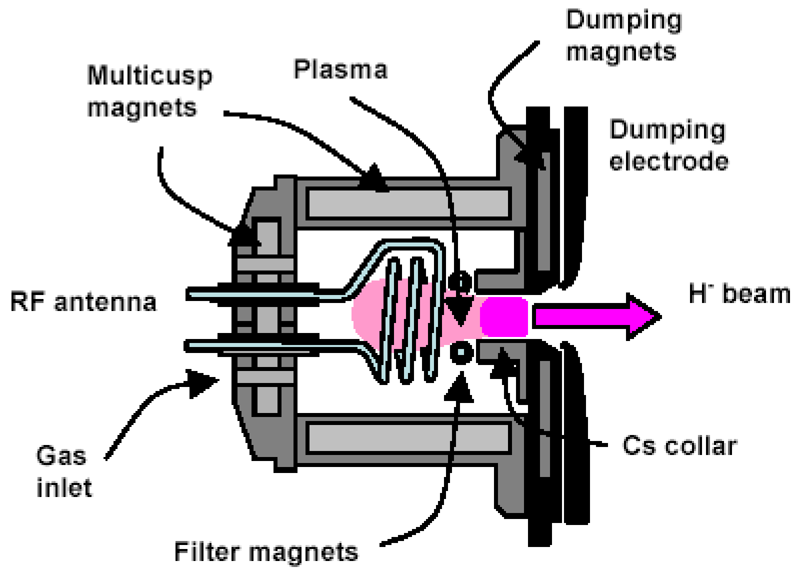
- beam blow up must be included in modelling calculations.

Conclusions cont.

Small gap between plasma- and extraction electrode and reduced thickness of the extraction electrode beneficial for beam optics.

- **electron deflection magnets in plasma- and extraction electrode?**

Plasma grid



Dumping magnets
Multicusp magnets
Plasma
Dumping electrode
RF antenna
H⁻ beam
Gas inlet
Cs collar
Filter magnets