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Ion retention, blocking and monitoring within the KATRIN experiment

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*Karlsruhe TRItium Neutrino experiment

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Overview

- Ion creation in KATRIN
- Ion influence in KATRIN experiment
- ICE method for monitoring
- Ion blocking with ring electrodes
  - Optimization
  - Neutralization
- Ion removal/monitoring with dipoles
- Conclusion

Ions created in KATRIN experiment

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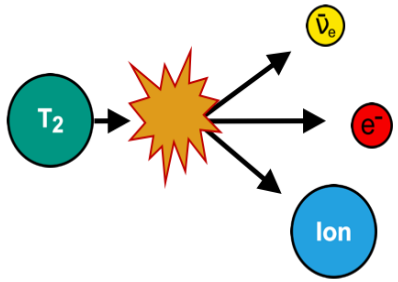
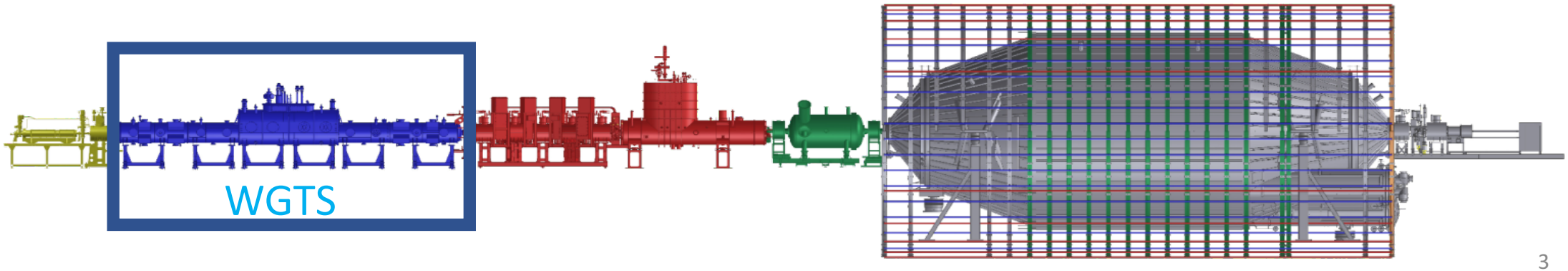
Ion creation rate in WGTS: Beta decay -> 10^{11} ions/s

Ionization -> 10^{12} ions/s



Energy: most ions have thermal energies ~ meV but ions created via molecular dissociation can have up to ~ 15 eV.

Recombination: with thermal electrons and between positive and negative ions.



Influence of ions on KATRIN measurement

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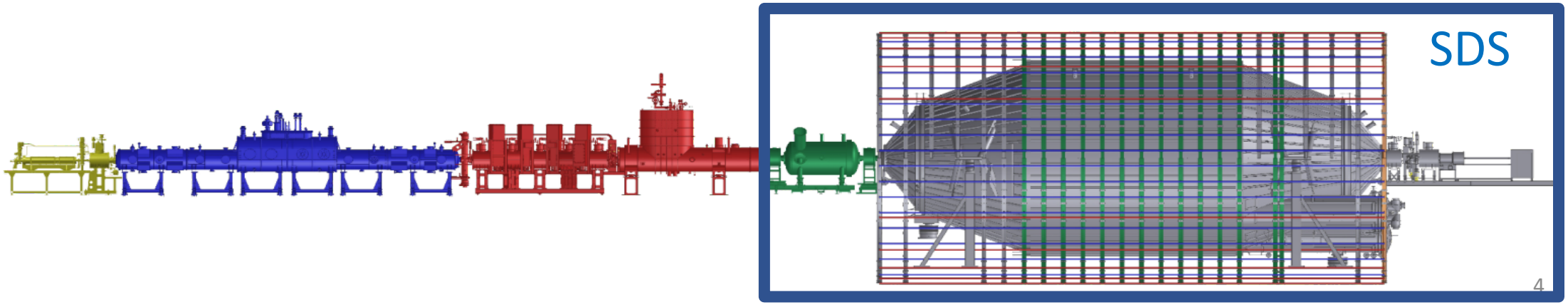
- Ions are magnetically guided to spectrometers

➔ **Contamination** of the spectrometers section (SDS)

➔ **Background** for neutrino mass measurement by

1. tritium decay
2. ionization of residual gas after acceleration by high voltage

Ion flux limit into SDS: 2×10^4 ions / s



Ion-conversion-to-electrons (ICE) measurements

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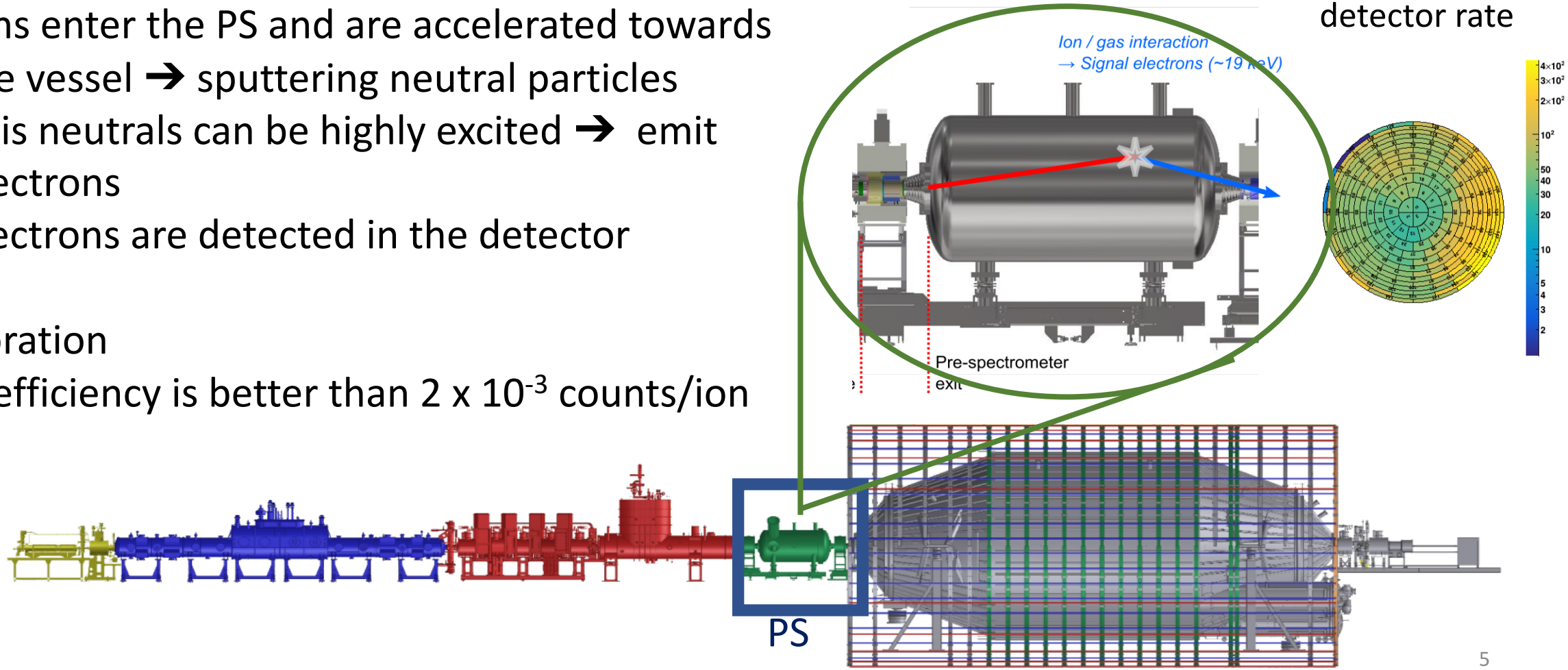
Method

- Ions enter the PS and are accelerated towards the vessel ➔ sputtering neutral particles
- This neutrals can be highly excited ➔ emit electrons
- Electrons are detected in the detector

Calibration

The efficiency is better than 2 x 10^{-3} counts/ion

Focal plane detector rate



Keeping ions away from spectrometers

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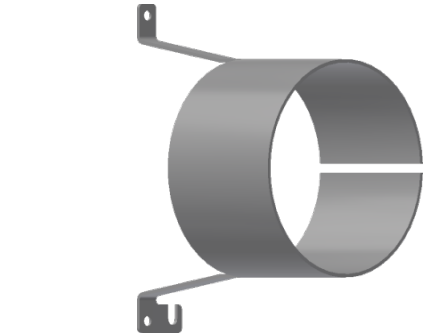
- **Ring electrodes** with positive voltages (up to +290 V)
- **Dipole electrode** with positive voltages (+25/+20)



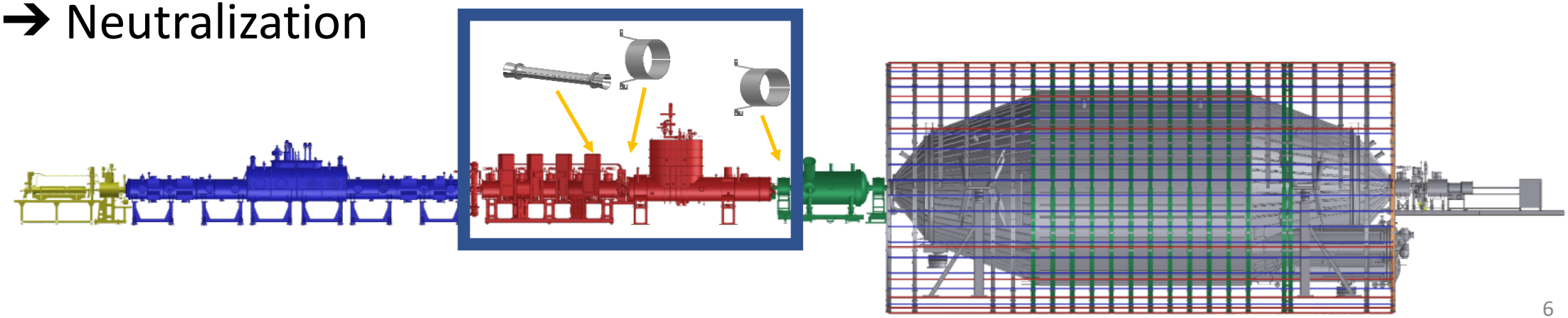
Consequences

➔ Blocking of ions

➔ Accumulation of ions in WGTS

➔ Possible creation of Penning ions

➔ Neutralization



Blocking devices optimal settings

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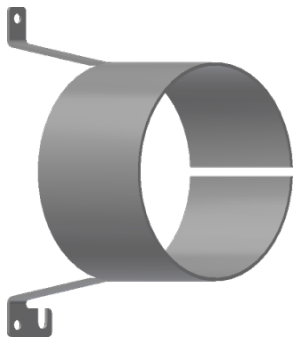
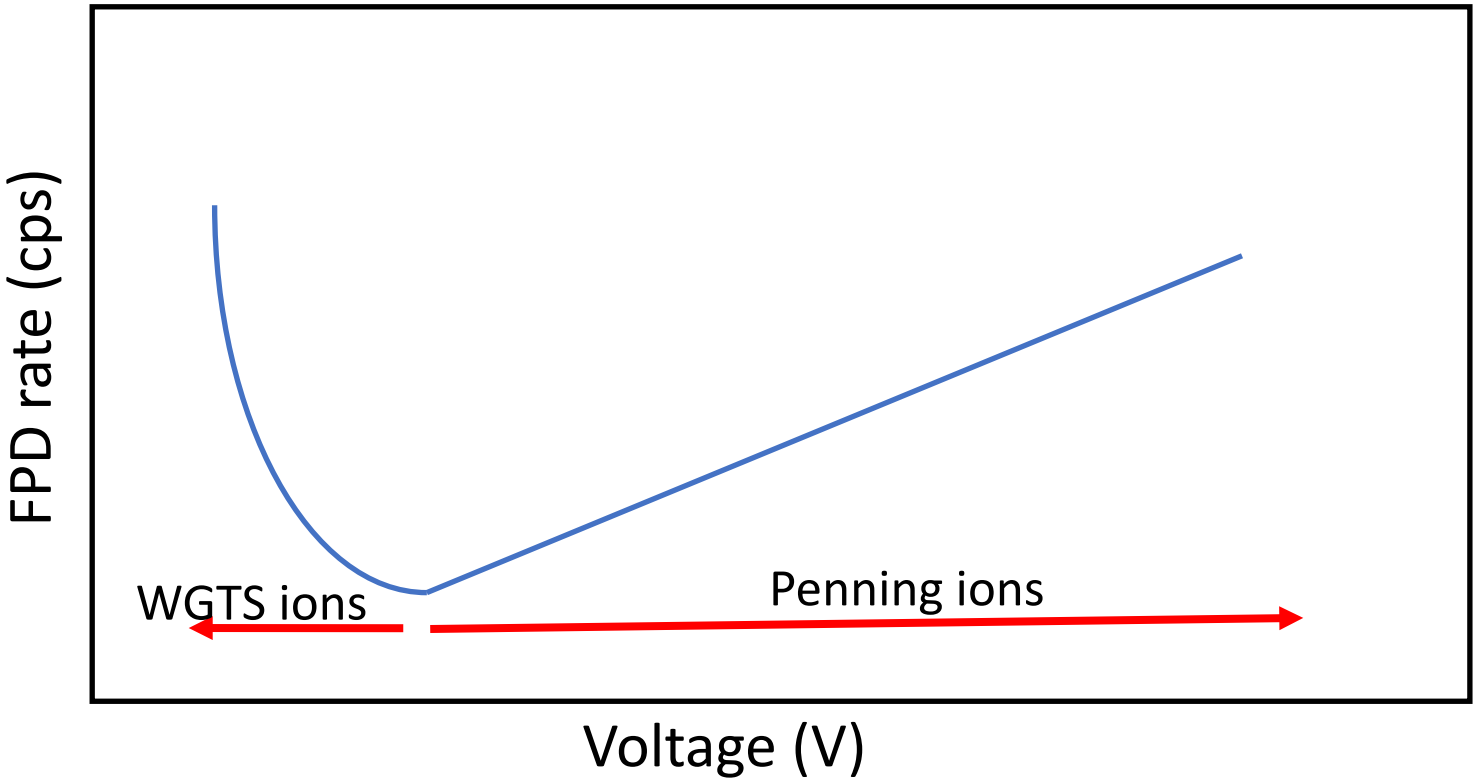
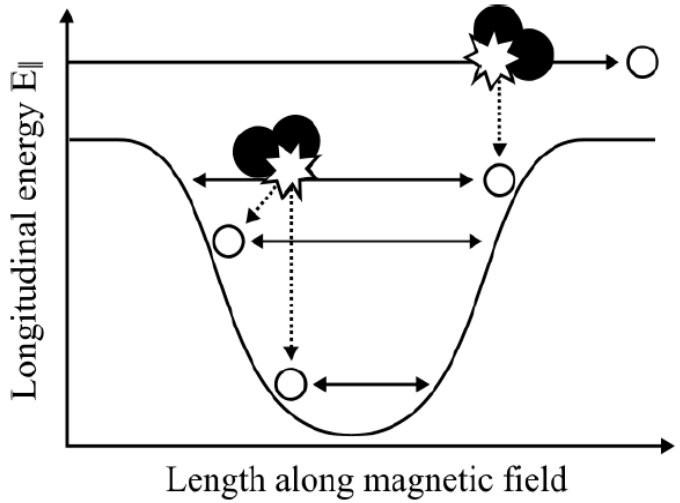


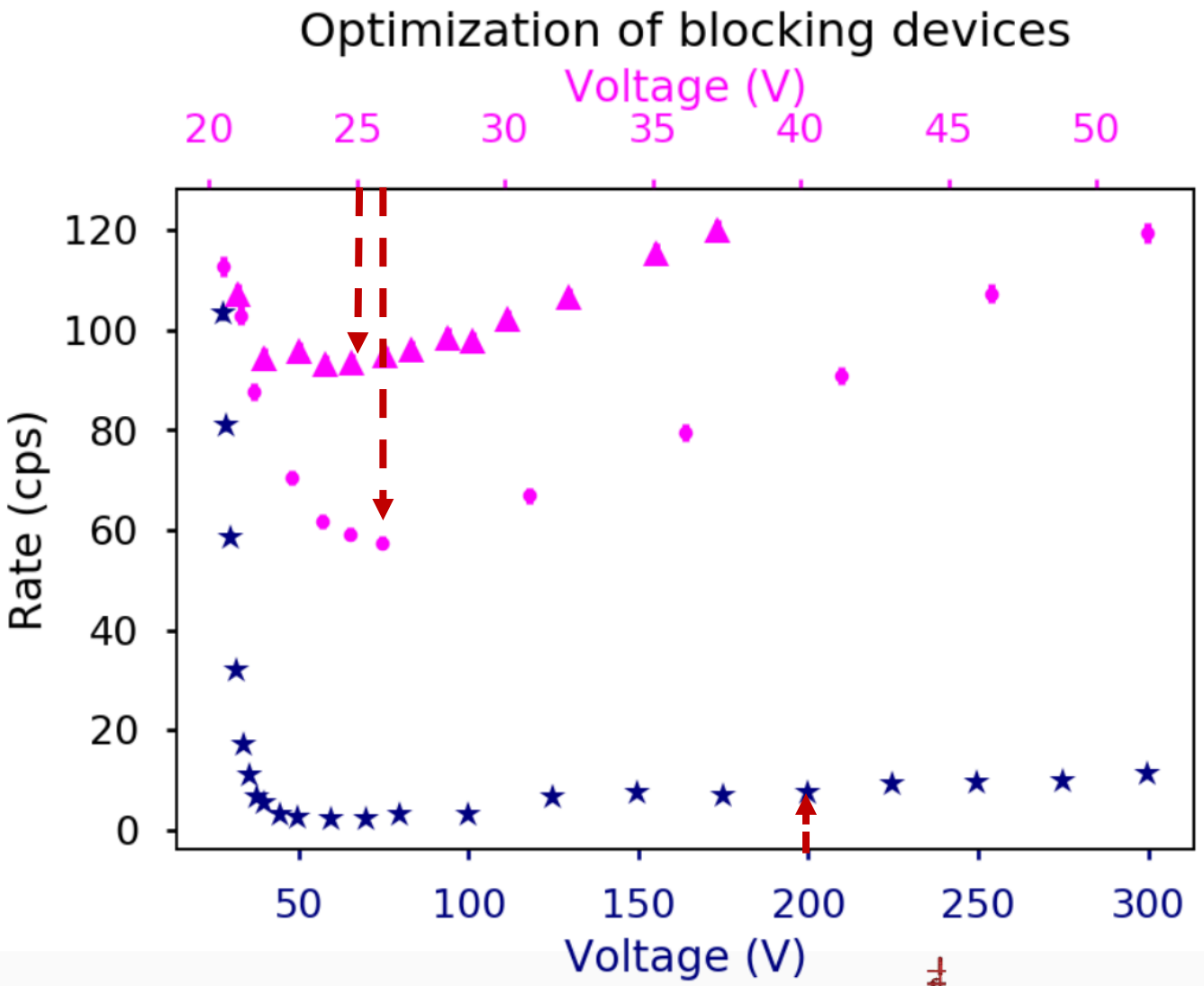
Ring electrode voltage scan expectation





Ions are created inside positive potentials by electrons colliding with residual gas.

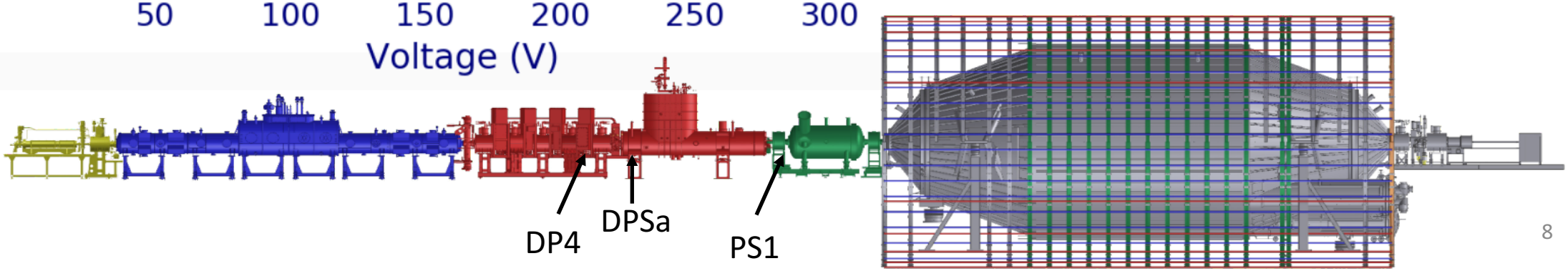
The optimal setting is NOT necessarily the maximum voltage due to penning ions.



The optimal settings are:

- PS1 -> 200 V because of low penning ion rate
- DP4 -> 25 V
- DPSa -> 26 V

Ions are being blocked!



Ring electrode neutralization

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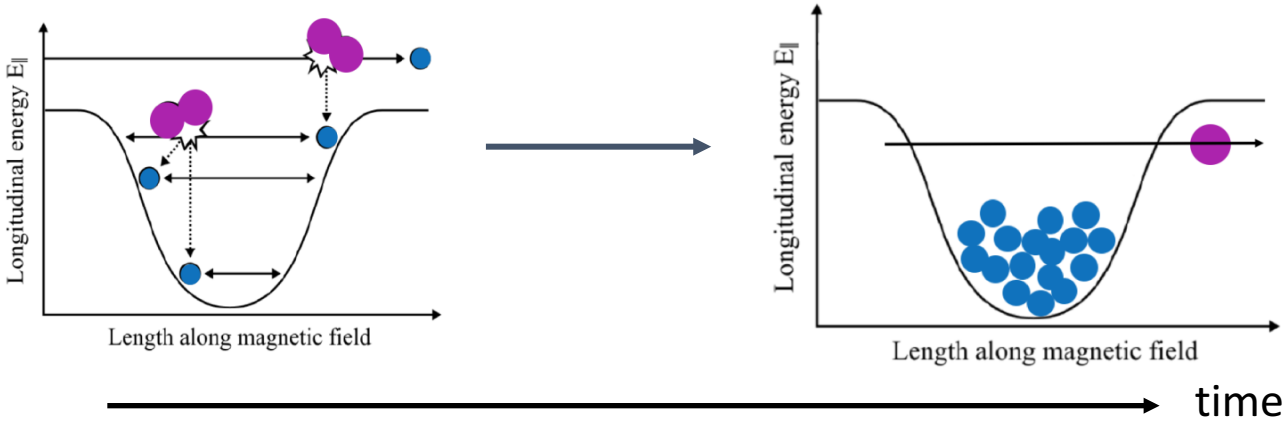
Before neutralization

After neutralization

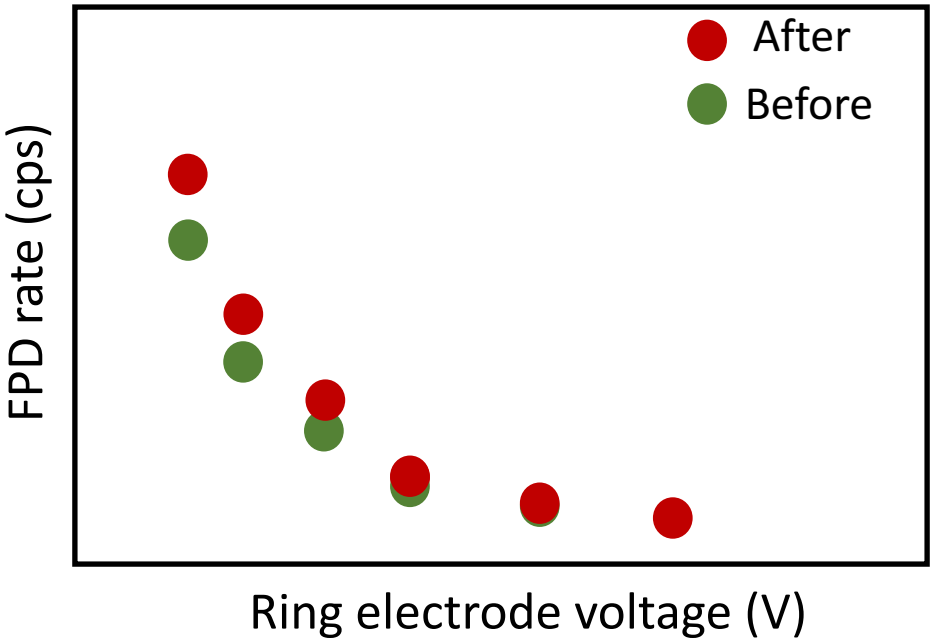


The blocking potentials will decrease with time as more electrons are captured in the potential.

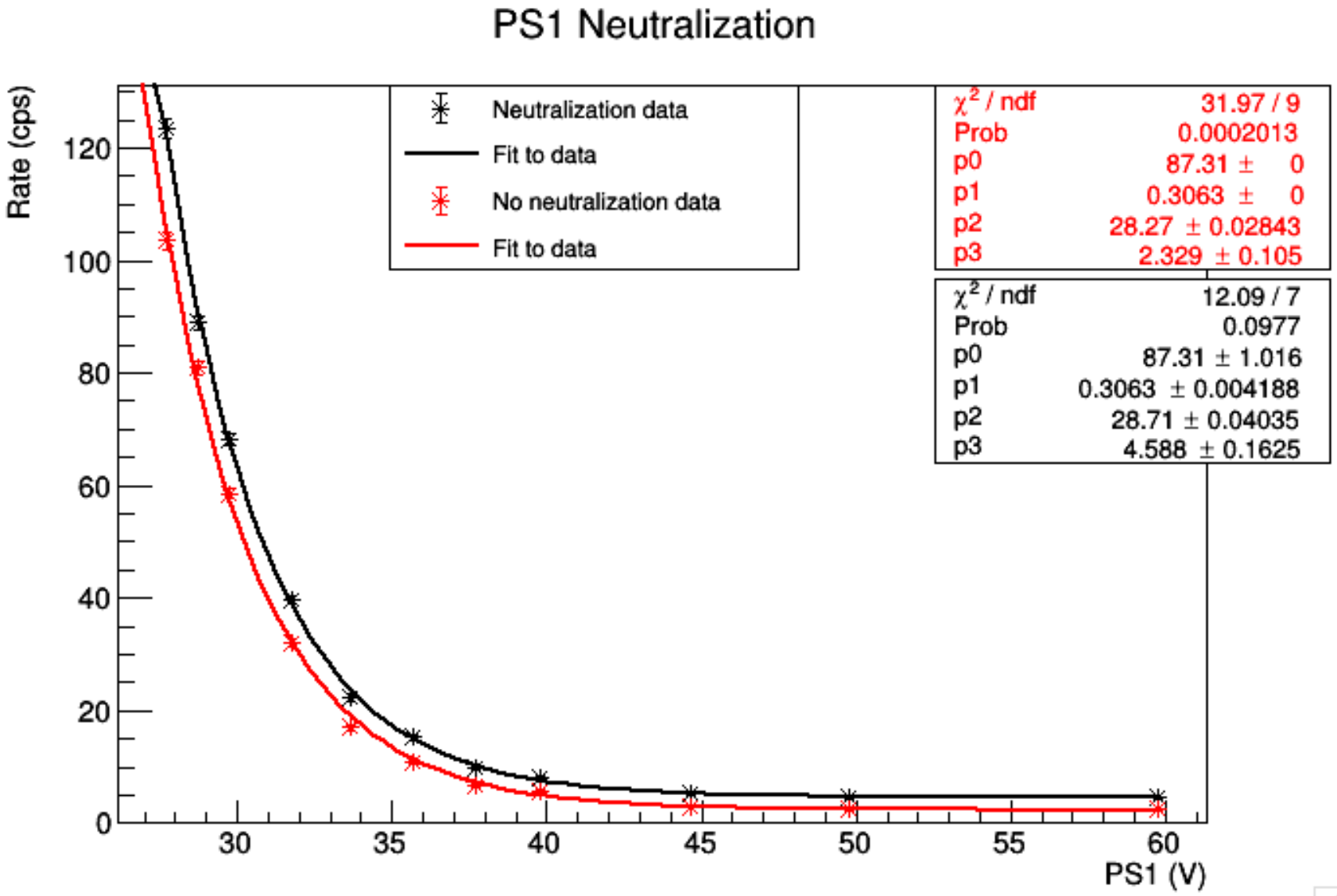
DANGERS!

- Ions are no longer blocked
- Contamination of PS and MS
- More background

Neutralization expectation



Neutralization times



Really long neutralization times.

DPSa -> no significant neutralization measured in 5 days.
PS1 -> no significant neutralization measured in 4 days.

Removing ions via dipole drift

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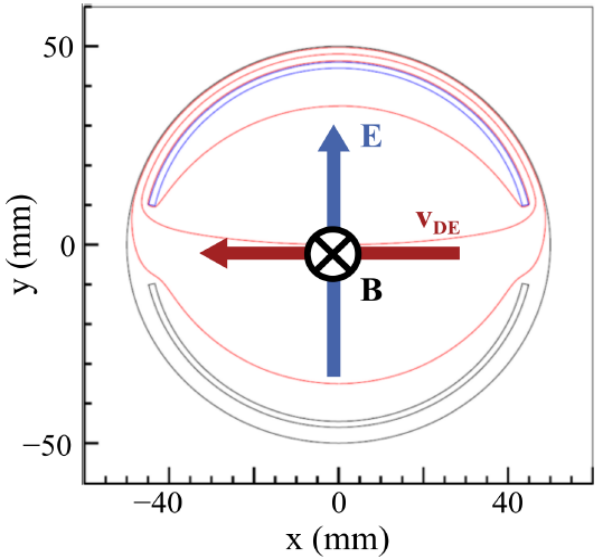
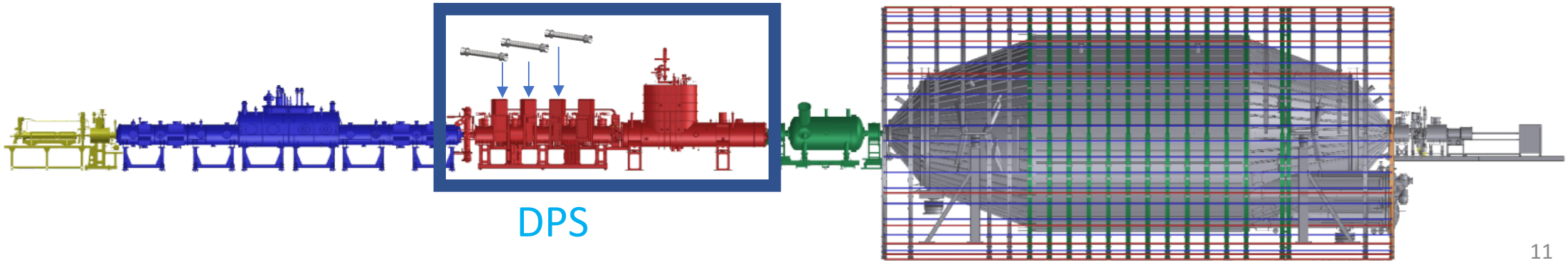
- **Four Dipole electrodes:**
  - 3 with negative dipole potentials to remove ions
  - Voltages: -15V/-5V, -35V/-5V, -85V/-5V



Consequences

➔ Ions drift in ExB direction, **they hit the lobes and are removed**

➔ Blocking of negative ions and secondary electrons



Removing ions: Dipole electrode currents

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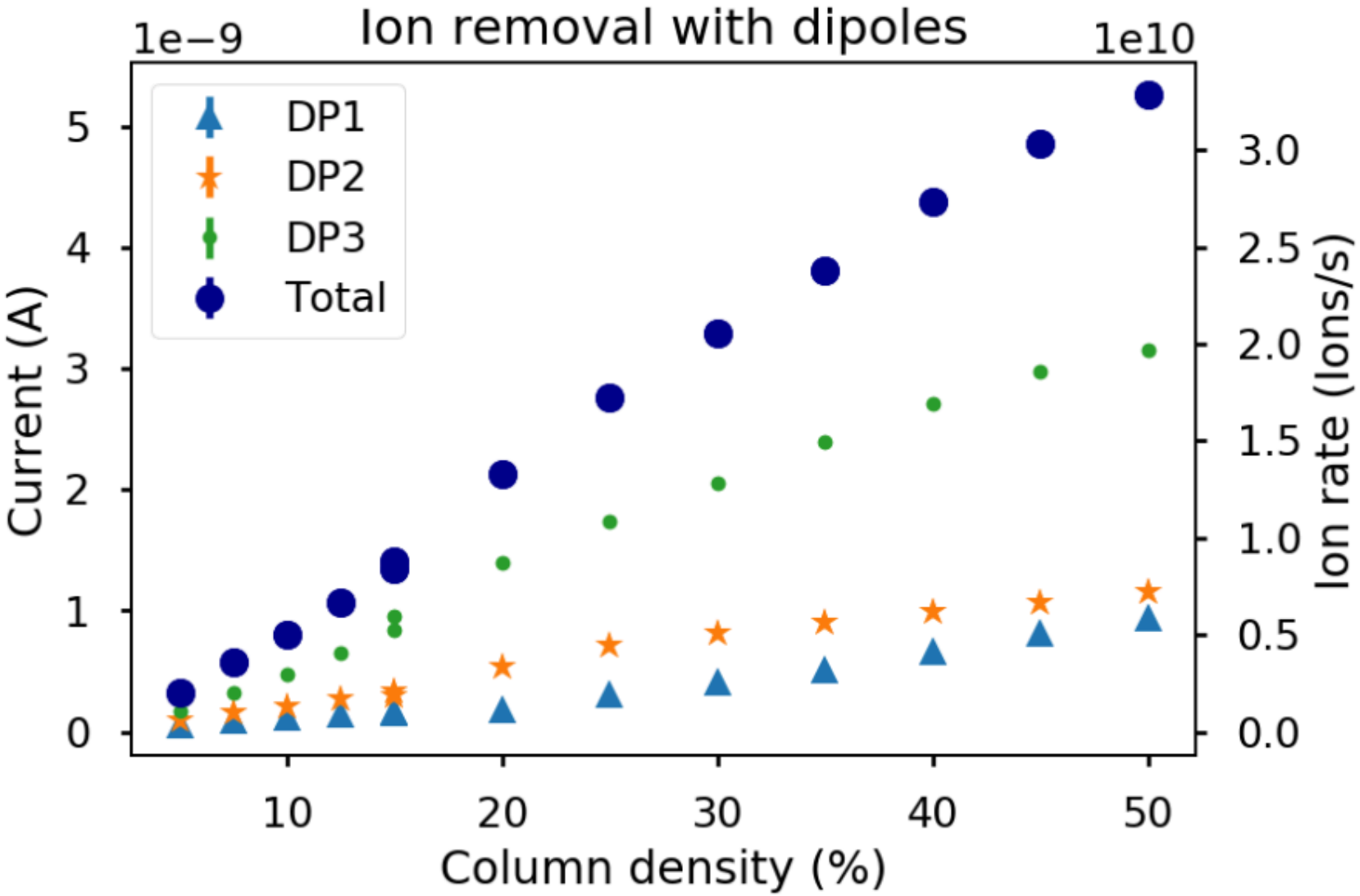

- Ions are being removed!
- The total current measured corresponds to ~2/3 of the removed ions in the DPS section. The rest don't hit the lobes.
- Slightly below expectations probably because of space charges in WGTS.

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Conclusions

- The ions created in the WGTS section are being blocked, before they reach the spectrometer section, by the ring electrodes and by the dipole 4.
- A optimal setting was found for the ring electrodes and dipole 4.
- Ions are being removed by the drift in the dipole electrodes with negative potentials.
- The neutralization times measured are really long so it is possible to run the experiment for a week before emptying the ring electrodes traps.

Thank you

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KATRIN collaboration
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- Ferenc Glück
- Manuel Klein

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KATRIN collaboration meeting 2019

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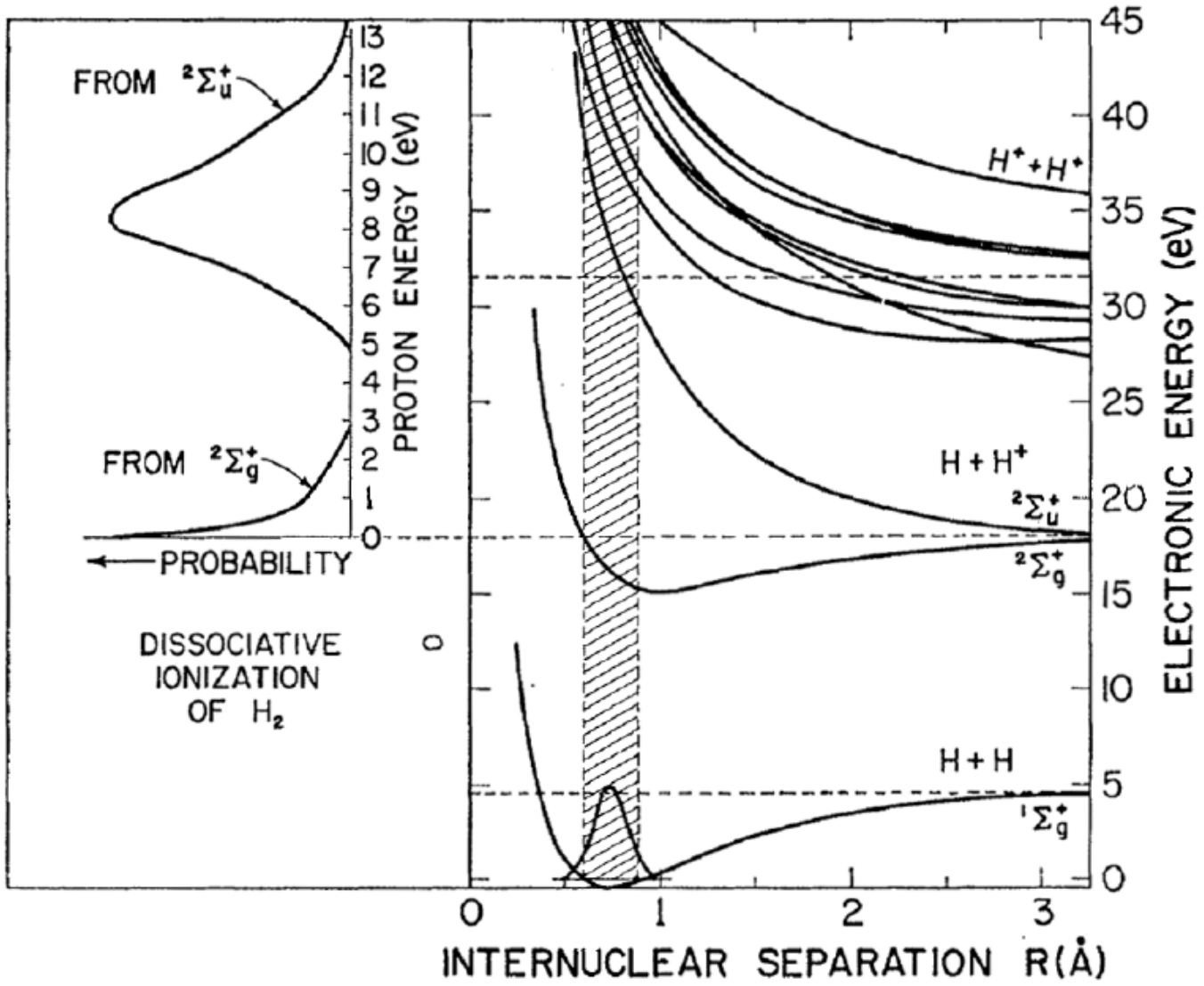
Backup slides

- Molecular dissociation



PhD M. Klein, 2018

Ion creation inside DPS (Penning ions)

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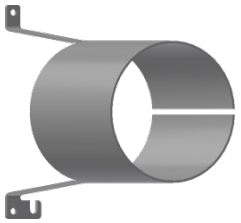
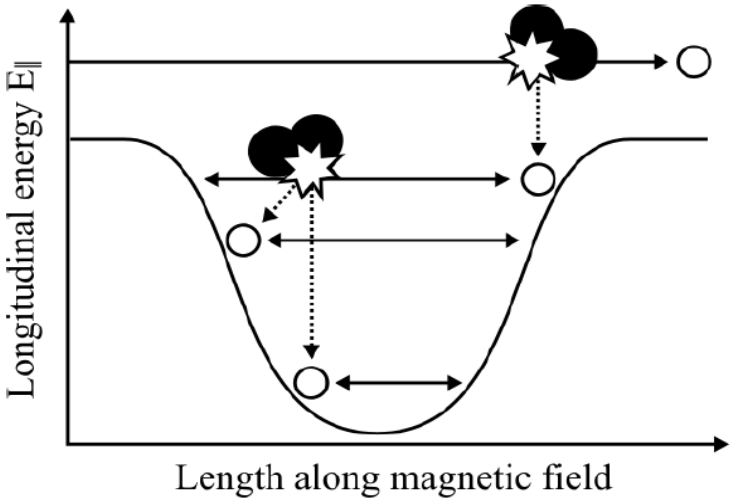
- Ion creation **inside of positive potentials** (e.g. ring electrodes)



- **Mechanism**
  1. Collision of electrons with gas
  2. Either primary or secondary electron is trapped
  3. Further collisions inside trap
  4. Number of stored particles increases with trap depth
  5. Electrons remain in trap; ions are accelerated away from trap



PhD thesis, M. Klein, 2018

➔ **Ion energy = trap potential**