LEIR cooling studies (magnesium + lead)

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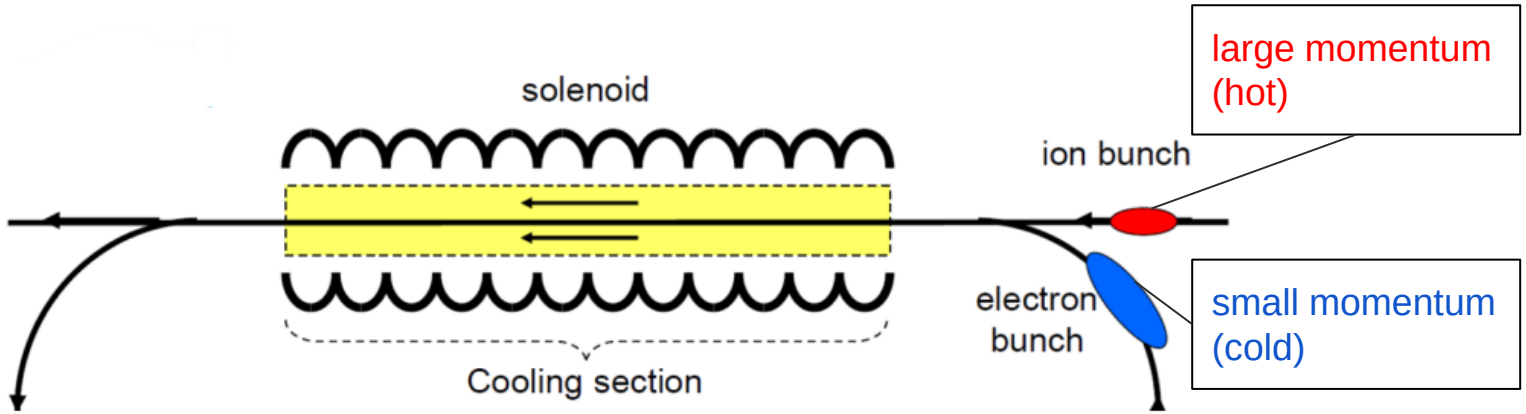
Acknowledgements: LEIR OP and Felix Carlier

Electron cooling introduction

- Goal: reduce emittance and momentum spread
- Electron cooling is the process of exchanging thermal energy between an ion beam and a co-propagating electron beam moving at the same average velocity
- Hot electrons are diverted and refreshed by new cold electrons

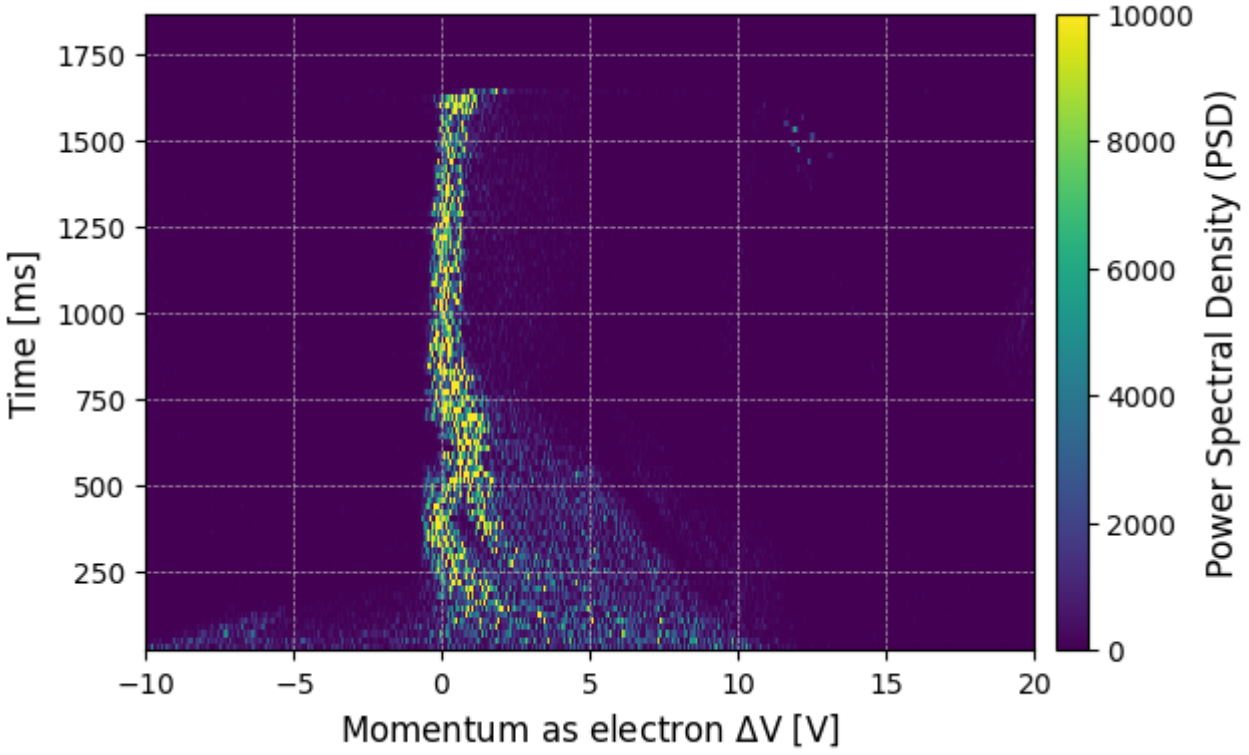


Solenoid guides electrons to improve cooling efficiency

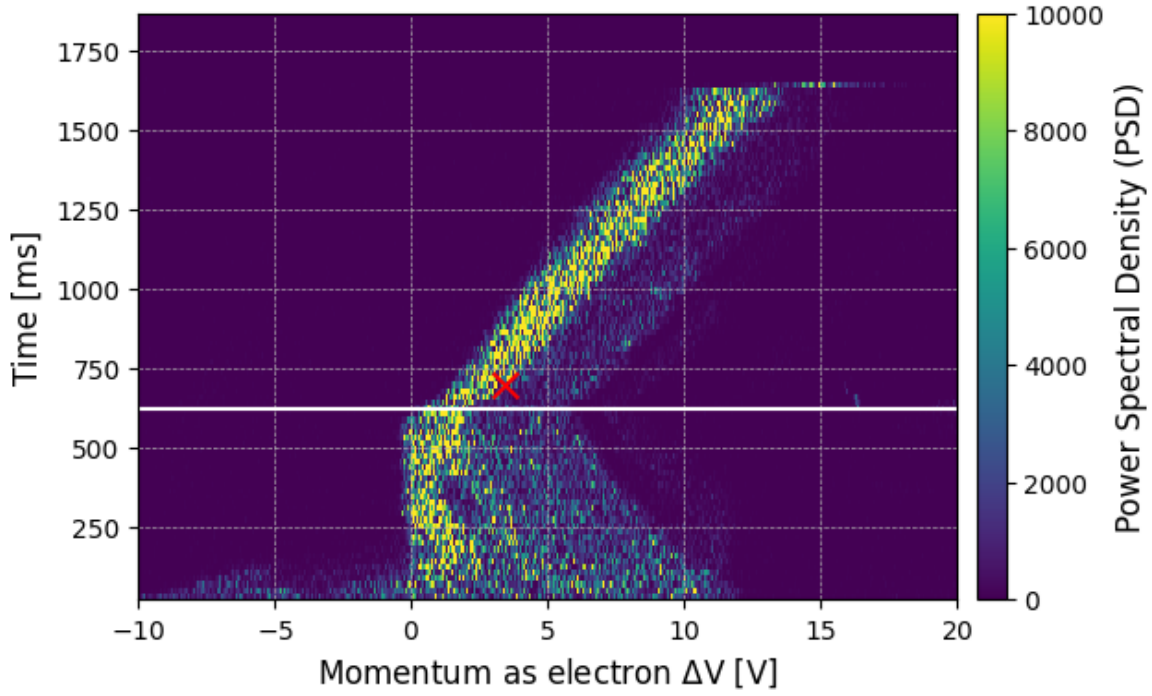
Magnesium 7+ measurement

Goal of MD: measure cooling performance for different voltages.

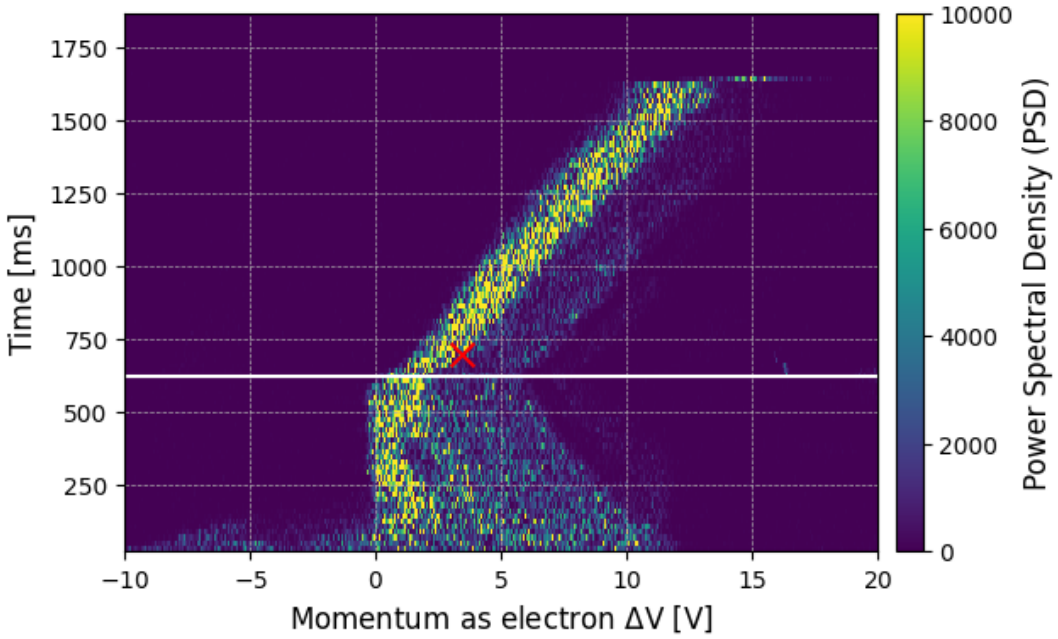
0V



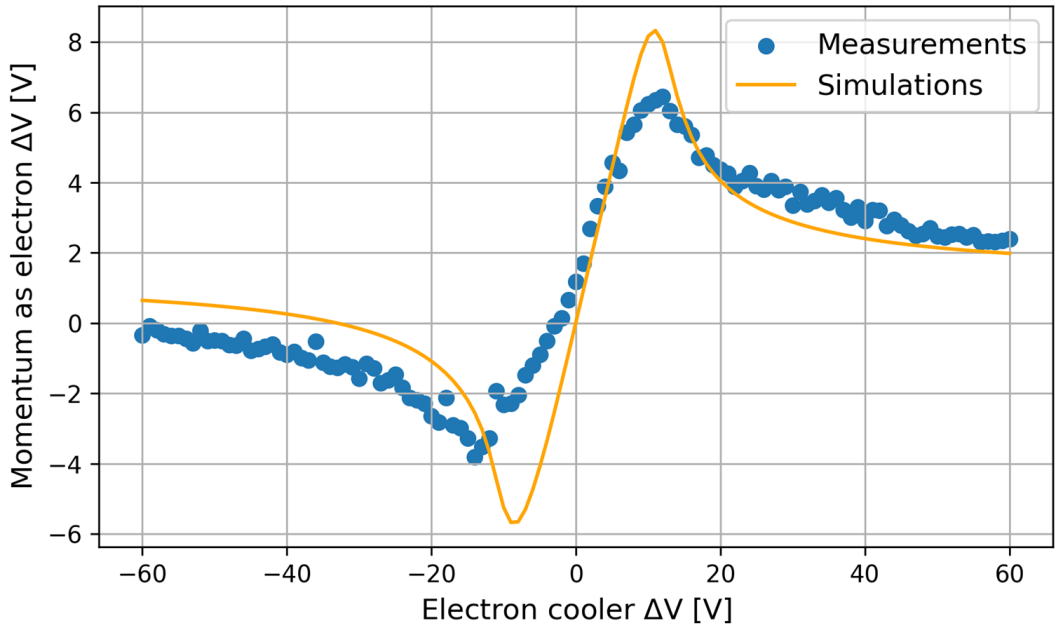
45V



Magnesium 7+ cooling performance



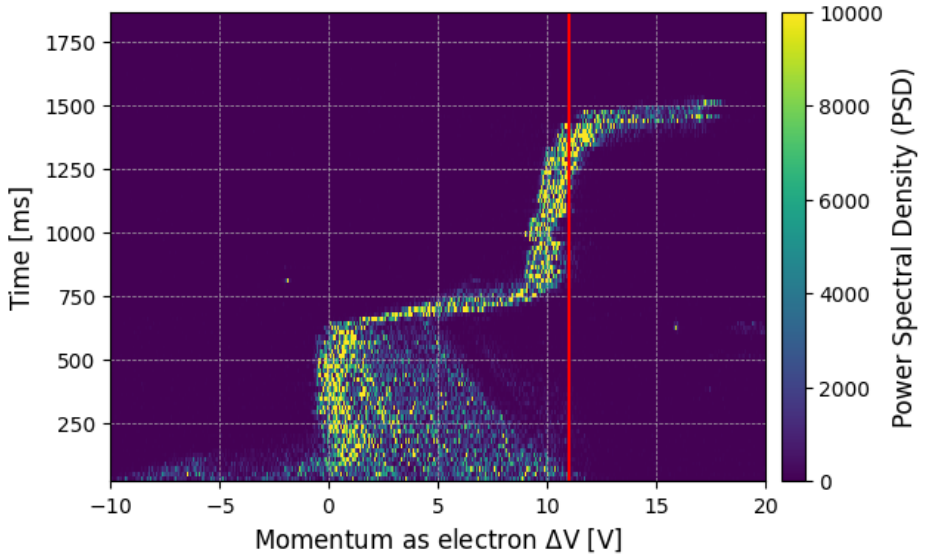
repeat for each voltage



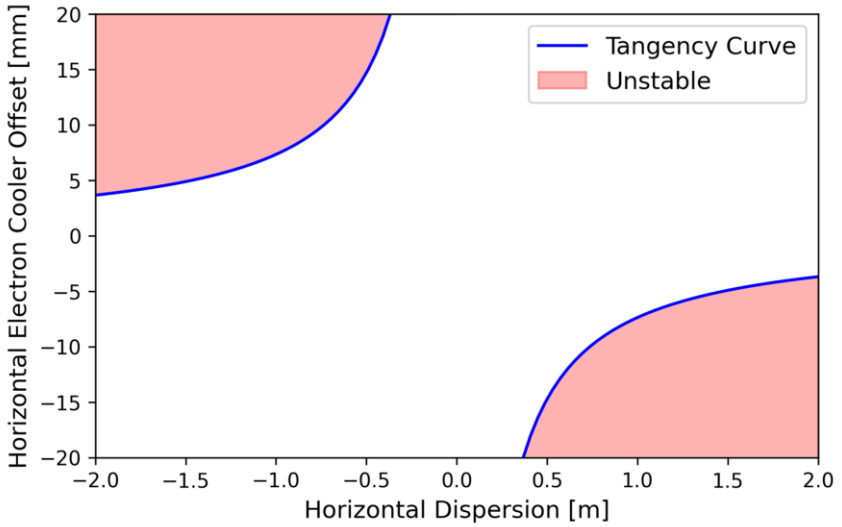
Simulations with Parkhomchuk model in Xsuite

Unexplained Instability

Beam velocity exceeds electron velocity!



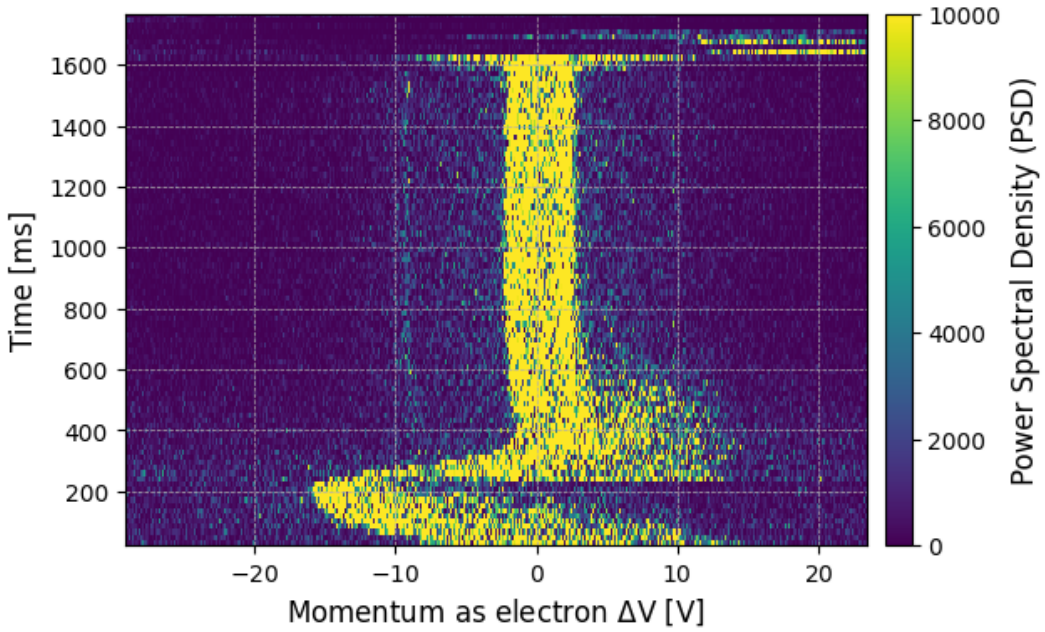
Possible explanation: high dispersion



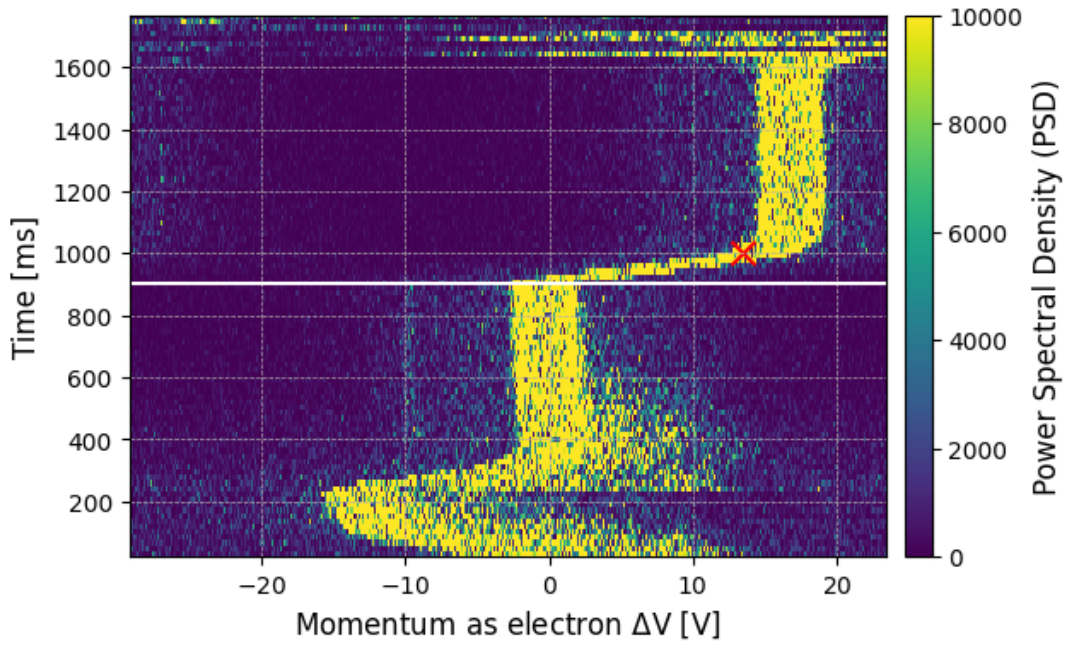
Question: can we find the instability for lead?

Measurement lead 54+

0V

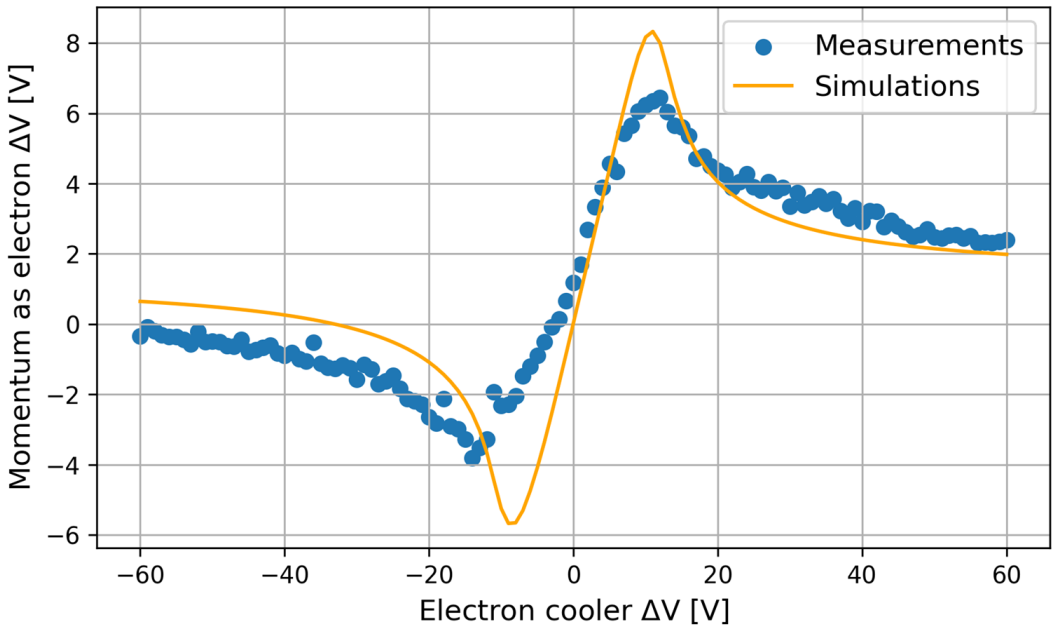


17V

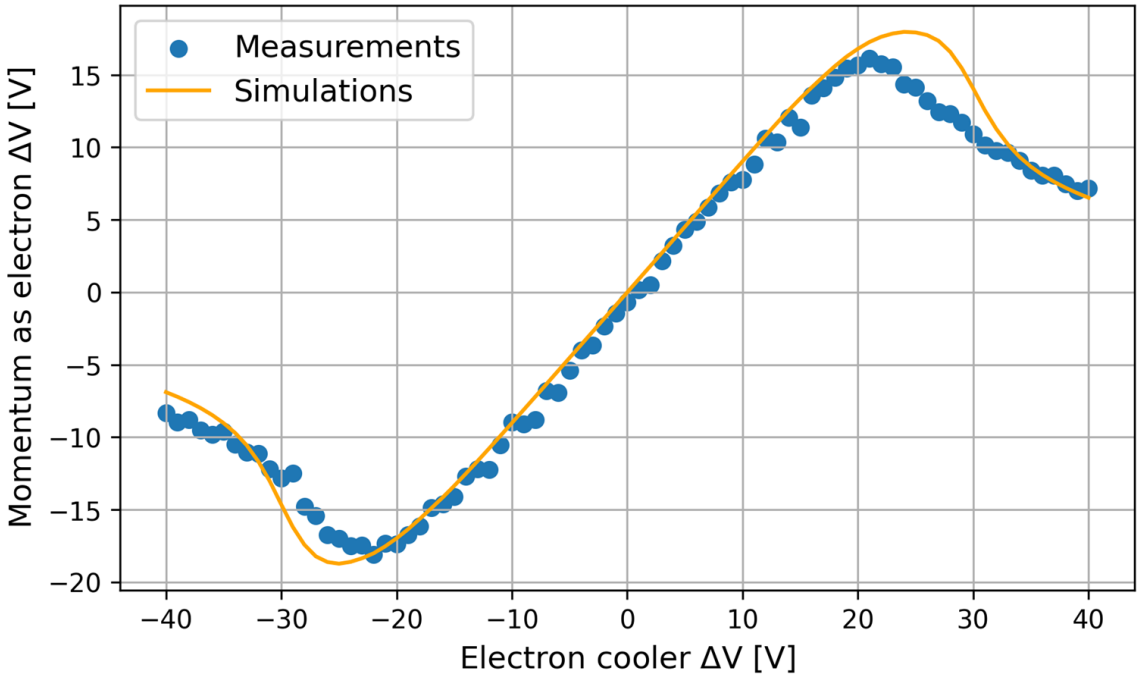


Cooling performance comparison

magnesium



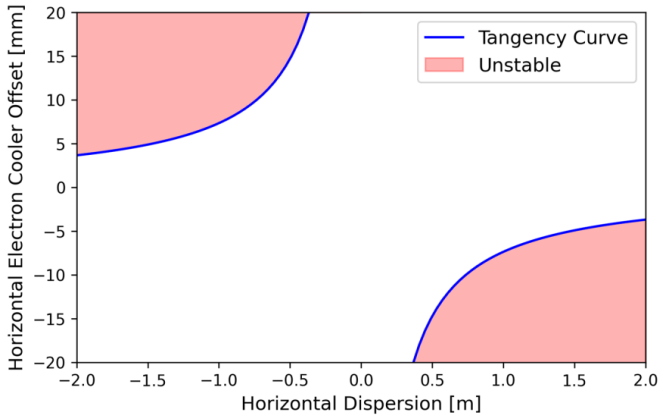
lead



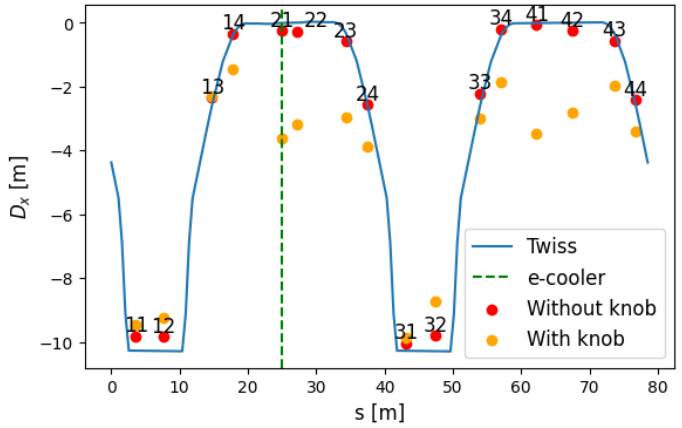
In future: longer pre-cooling

Probing the instability

Try to probe instability on purpose

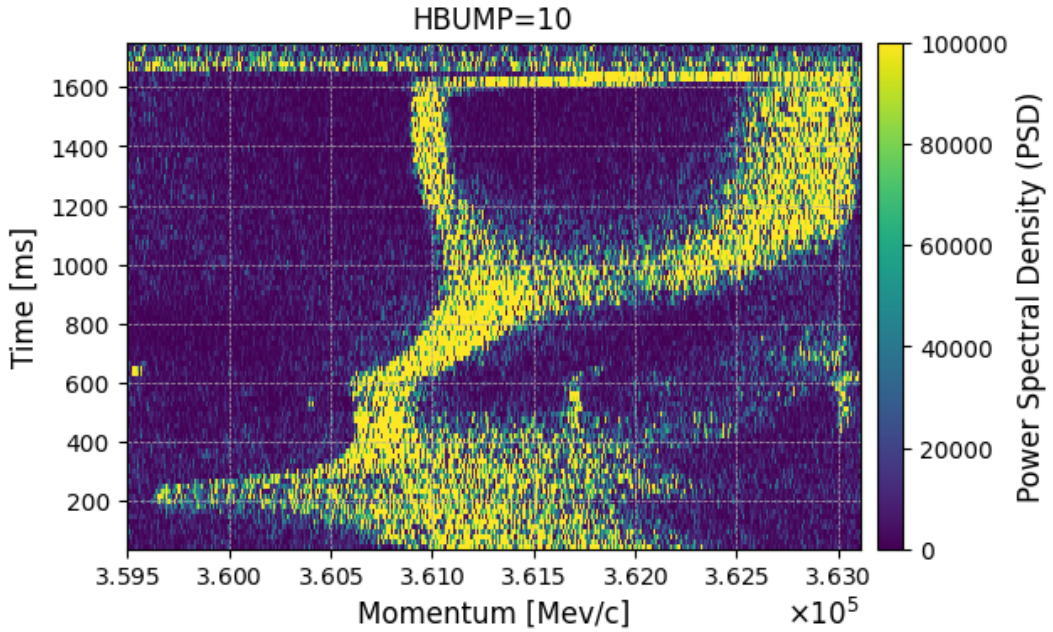


Use high dispersion at e-cooler



Courtesy of F. Carlier

We never found the instability for lead



Future MD’s

Future MD’s:

- Try to recreate unexplained magnesium instability
- Measure cooling performance for other ions (oxygen)

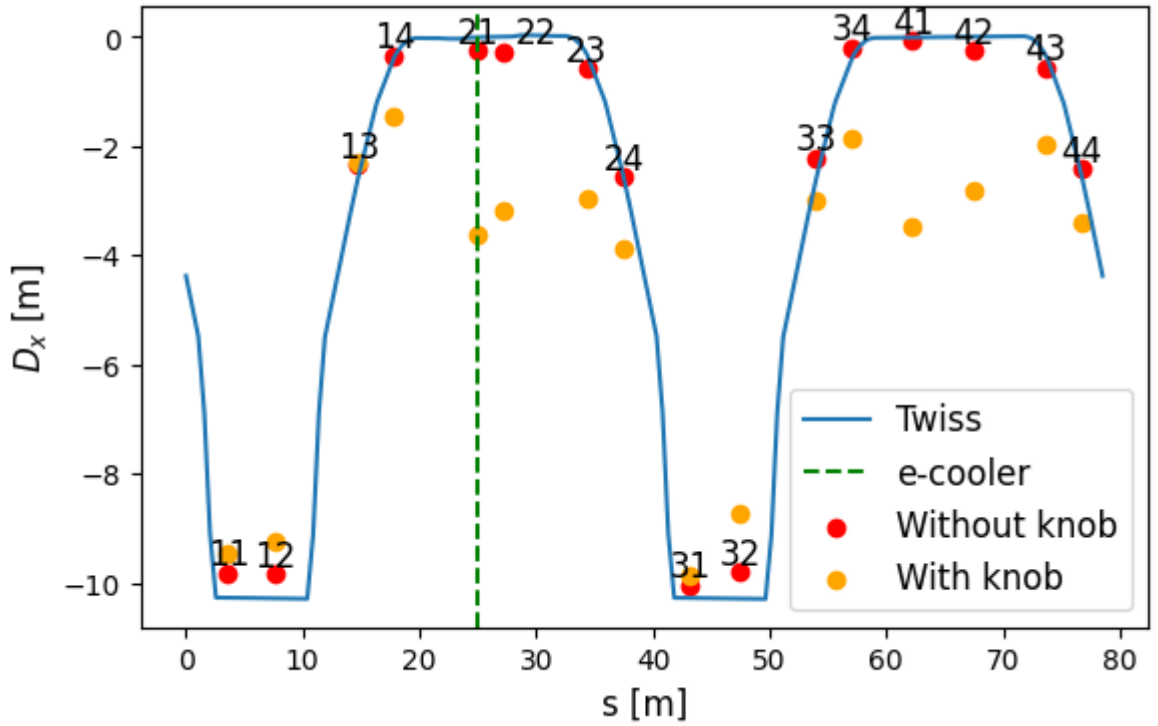
MD specifications:

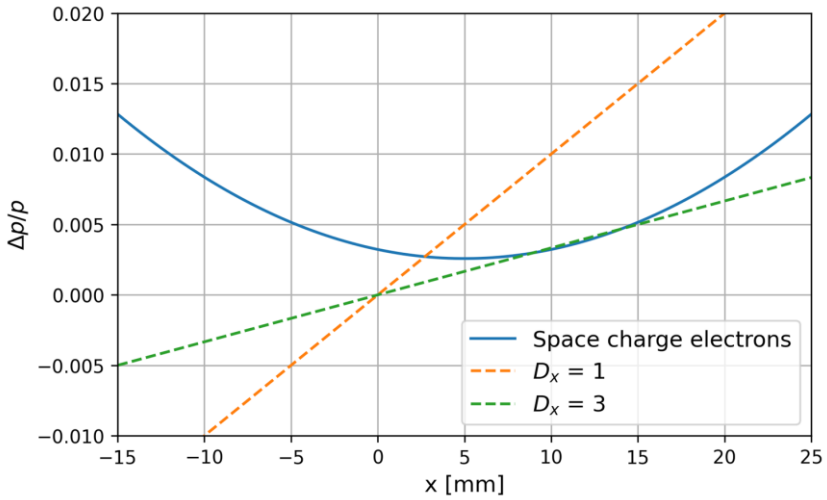
- Ensure long pre-cooling time
- Preferably, low intensity single injection to avoid any heating effects

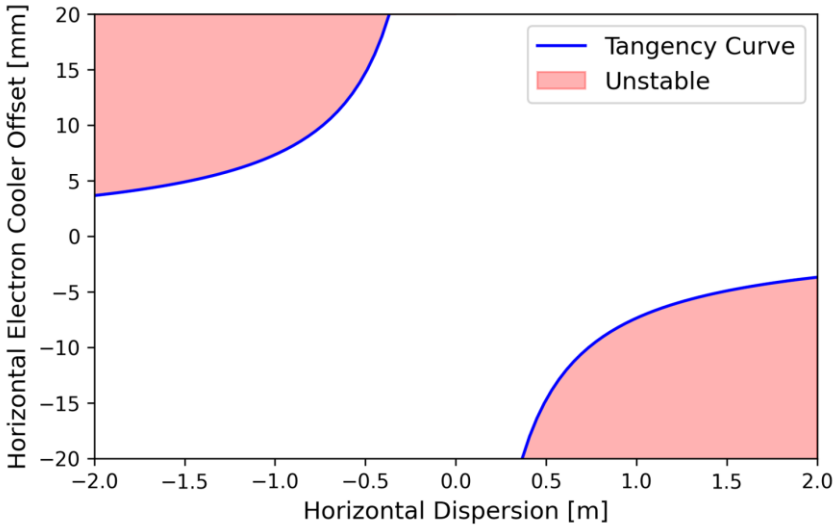
Backup

LEIR dispersion measurement

look for instability with dispersion knob

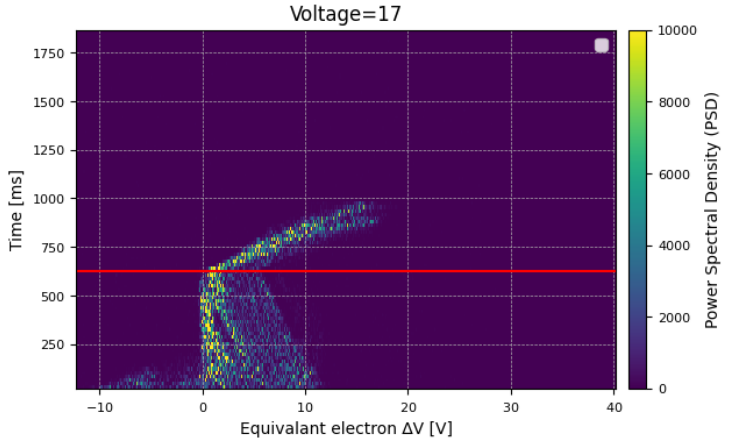



0.020
0.015
0.010
0.005
0.000
−0.005
−0.010
Δp/p
−15
−10
−5
0
5
10
15
20
25
x [mm]
Space charge electrons
$D_x = 1$
$D_x = 3$

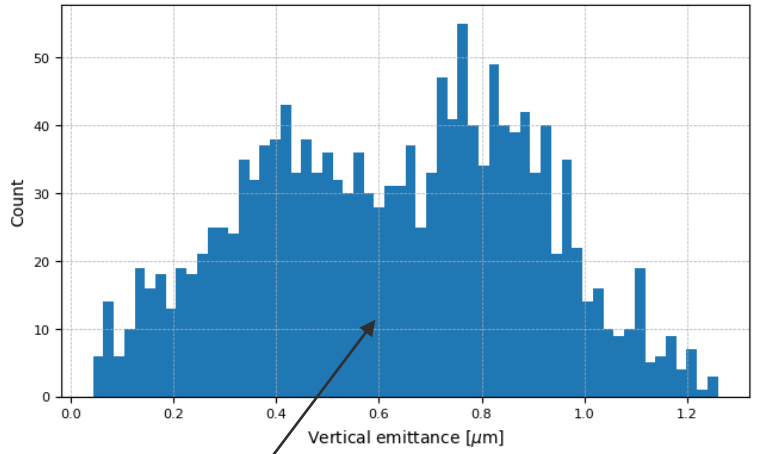

Horizontal Electron Cooler Offset [mm]
20
15
10
5
0
−5
−10
−15
−20
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
Horizontal Dispersion [m]
Tangency Curve
Unstable

IPM data

Question: what is starting emittance of simulation?



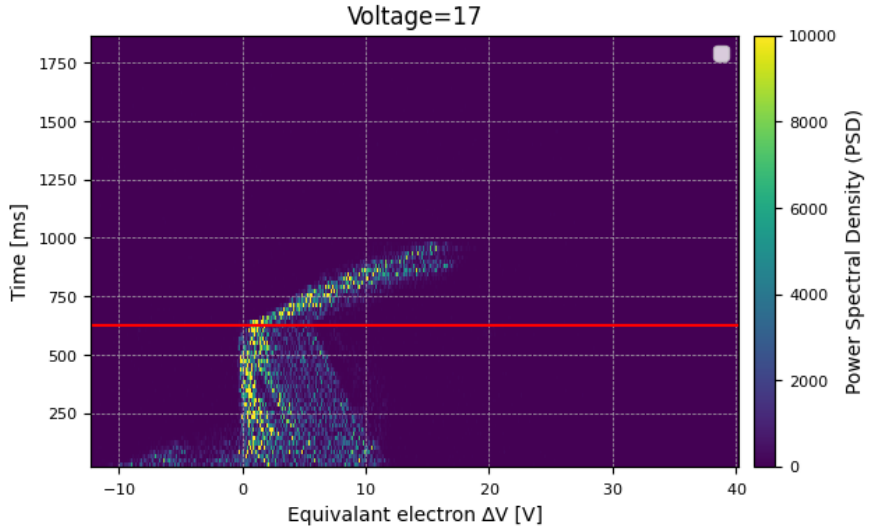
Distribution over all measurements



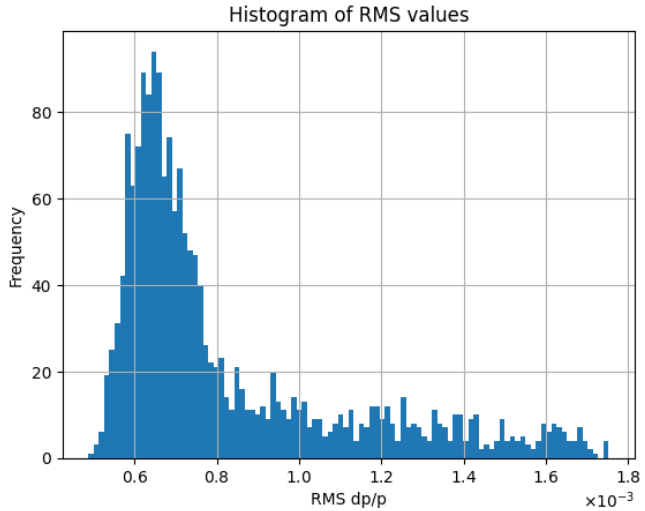
simulations done with mean(0.6)

No, x so assume round beam

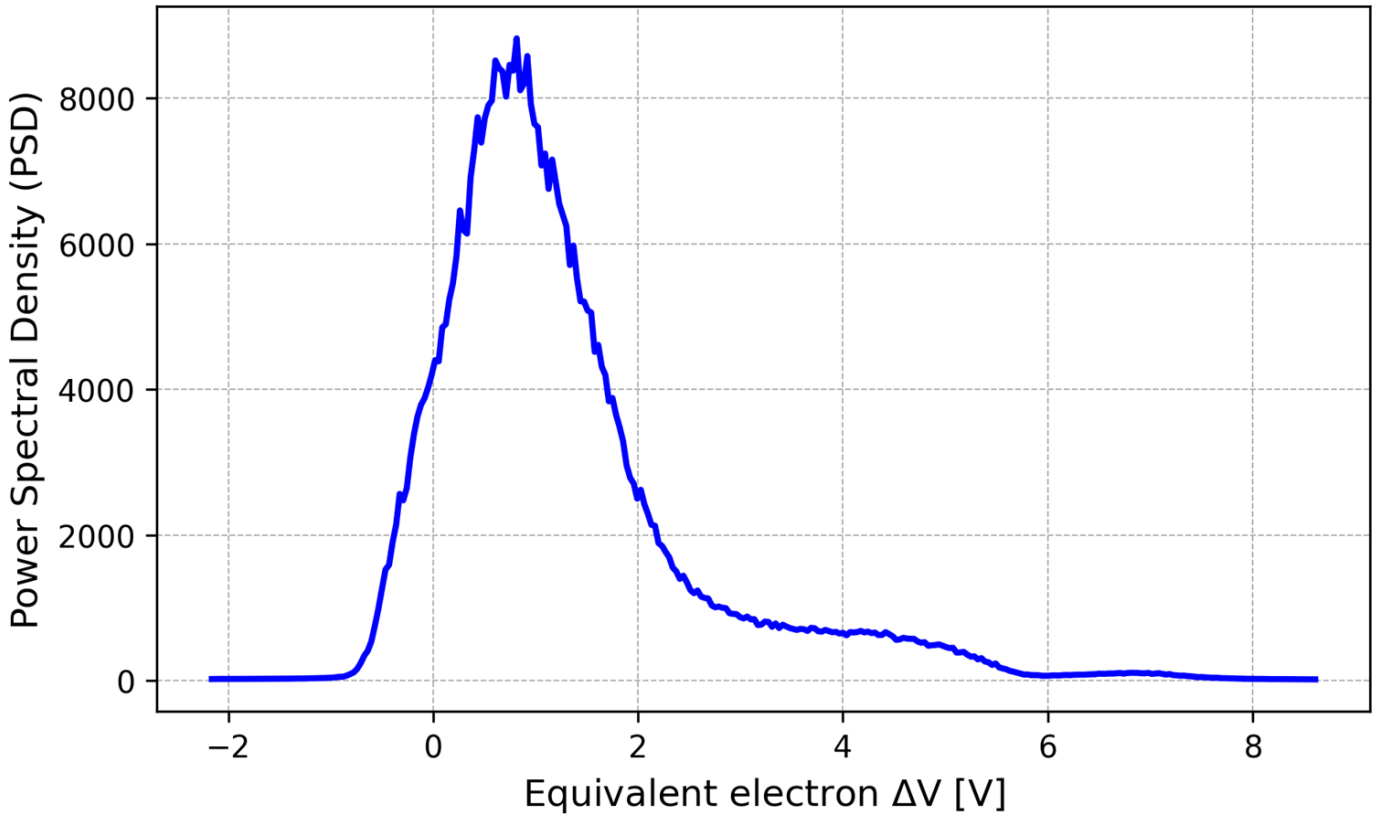
Schottky data

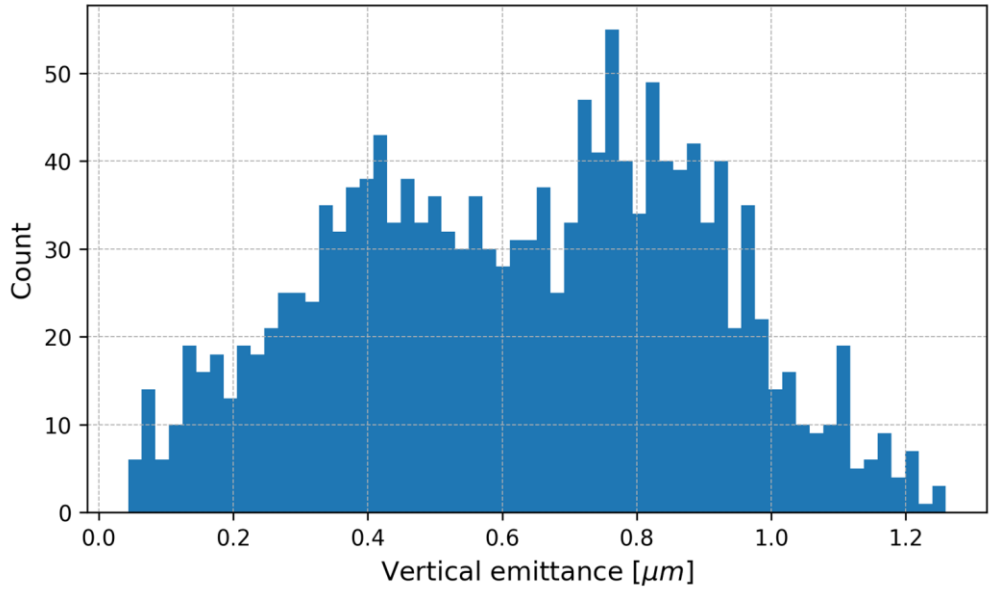


Distribution over all measurements



simulations done with most frequent value (0.6)


Power Spectral Density (PSD)
8000
6000
4000
2000
0
−2
0
2
4
6
8
Equivalent electron ΔV [V]


Count
50
40
30
20
10
0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Vertical emittance [μm]