High Intensity Ion Beam Extraction System for FECR

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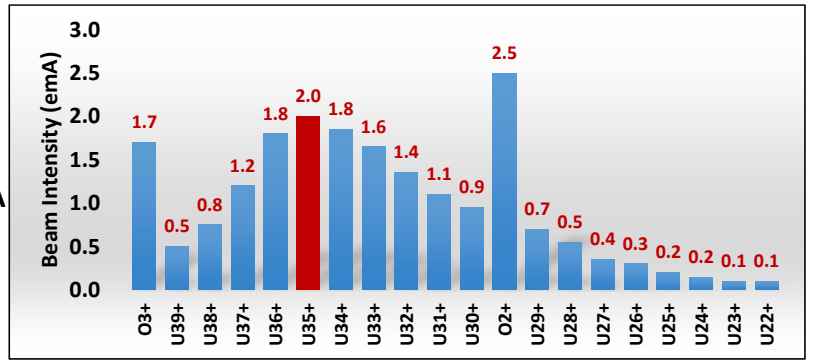
FECR: the 4th Gen ECRIS

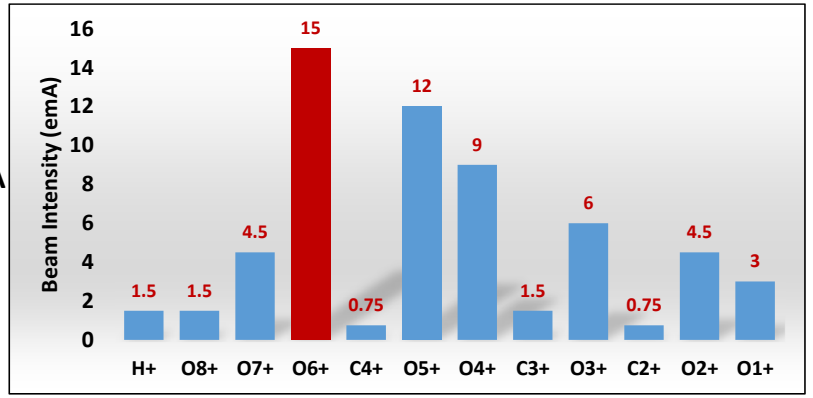
Beam Requirements for FECR	
Extraction Voltage (kV)	50(max)
Total Drain Current (emA)	20~60
Highest Ion Beam Intensity (emA)	>10.0($^{16}O^{6+}$) >2.0($^{78}Kr^{19+}$) >1.5($^{129}Xe^{26+}$) >1.0($^{238}U^{35+}$)
Emittance(π·mm·mrad)	$\varepsilon_{n,rms} \leq 0.20$
Energy Spread	$\Delta p/p < \pm 5.0 \times 10^{-3}$

Beam Distribution for Extraction Simulation

20 emA U



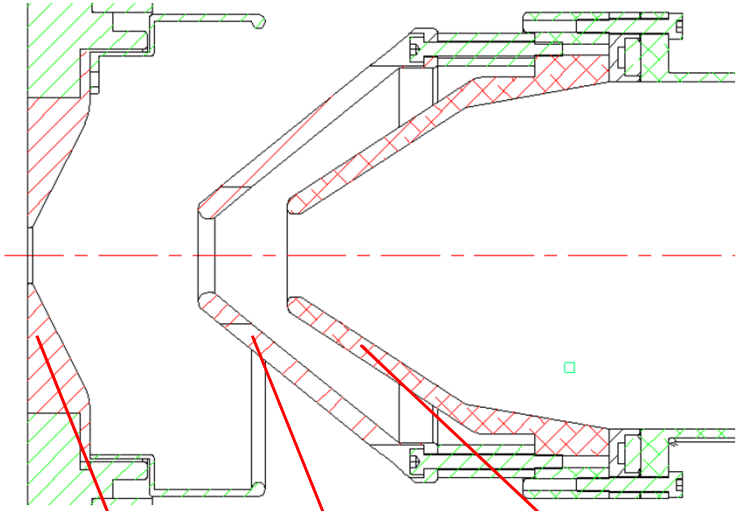
60 emA O



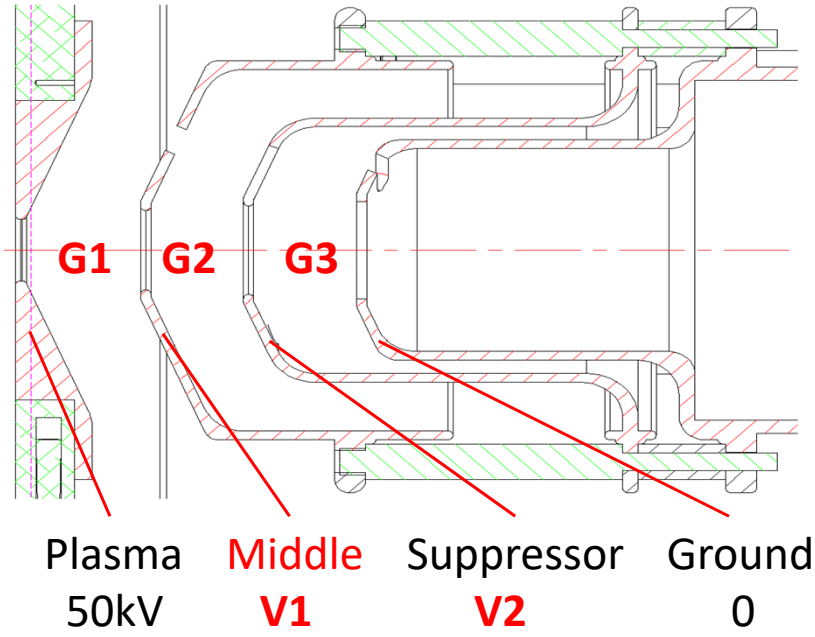
Ref: L. Sun, et al. Intense Beam Production of Highly Charged Ions by the Superconducting ECR Ion Source SECRAL for Heavy Ion Linacs.

FECR: 4-electrode Extraction System

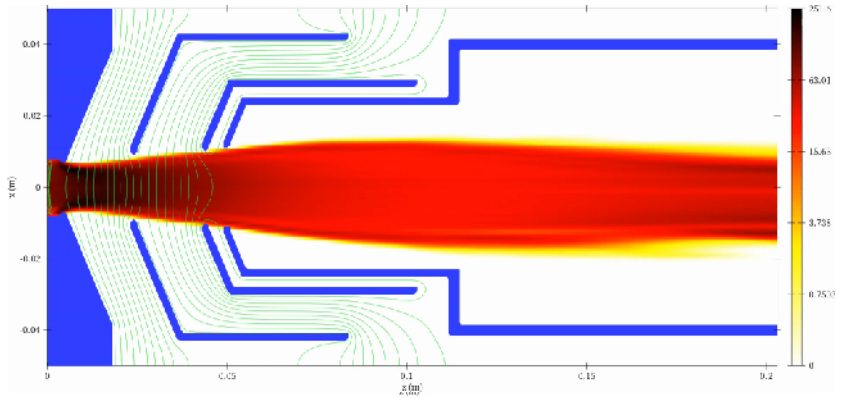
3-electrode Extraction for SECRAL

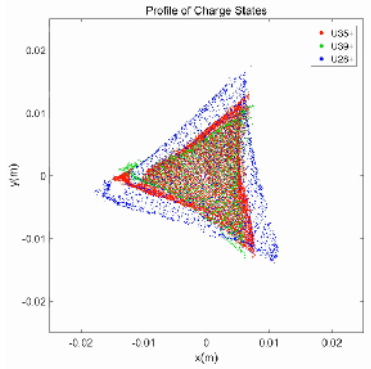


4-electrode Extraction for FECR

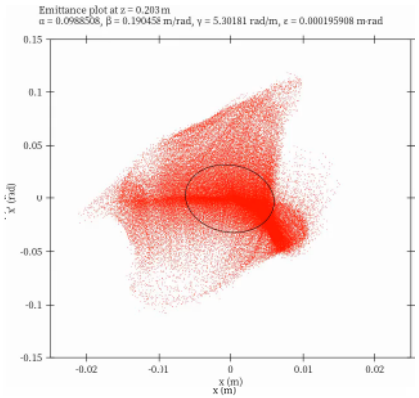


IBSIMU: G1= 20~47mm_V1= 23kV(U)

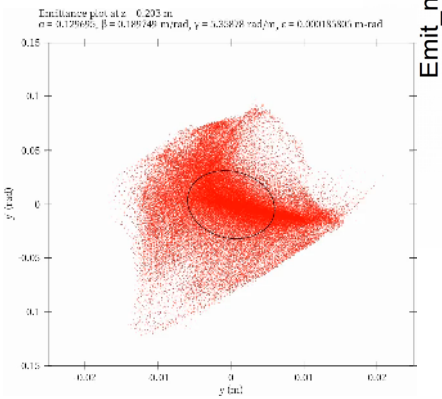


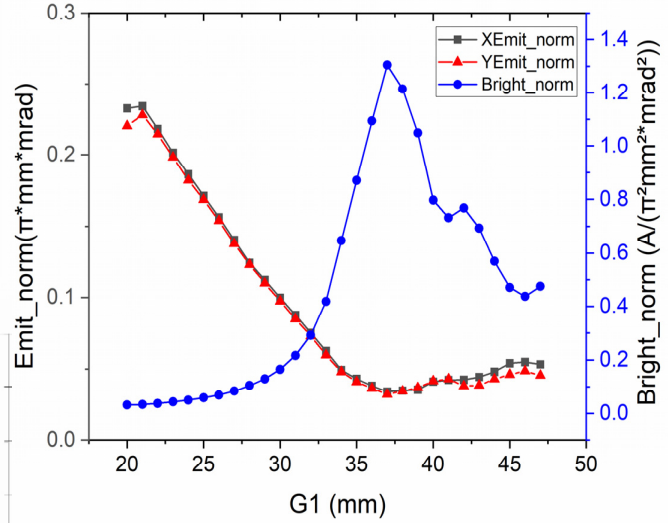


All Particles
X Emittance



All Particles
Y Emittance



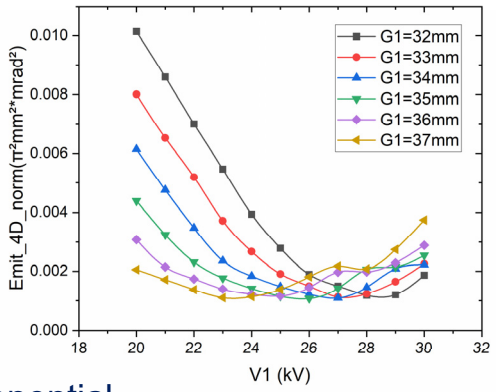


U^{35+} Beam Quality
at the End of Extraction
(200mm)

Ref: Kalvas T, et al. IBSIMU: A three-dimensional simulation software for charged particle optics[J].

Optimizing G1&V1

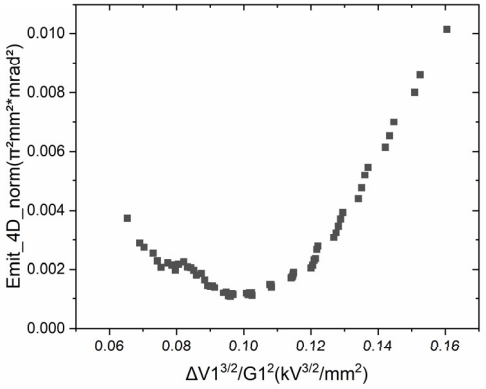
U^{35+}



Exponential

$$j = \frac{P_0}{9\pi d^2}\left(\frac{Z}{A}\right)^{\frac{1}{2}} {U_0}^{3/2}$$

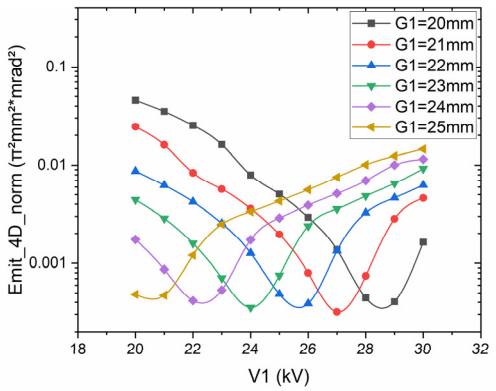
$$P_0 = 1.54 \times 10^{-6} P$$

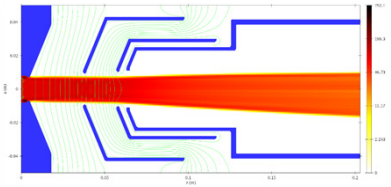


$$\Delta V^{3/2}/G1^2 \approx 0.10$$

$$k \approx 2.19 \times 10^{-6} P$$

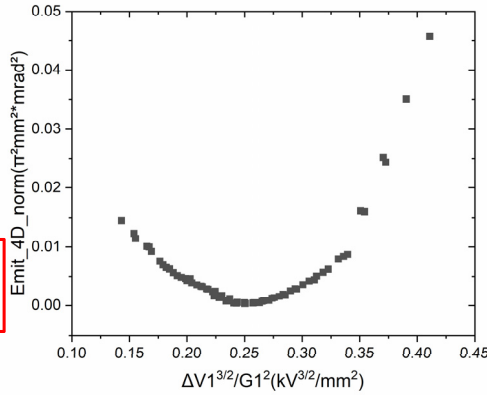
O^{6+}





$$j_{opt} = \frac{k}{9\pi G1^2}\left(\frac{Z}{A}\right)^{\frac{1}{2}} \Delta V1^{3/2}$$

k?

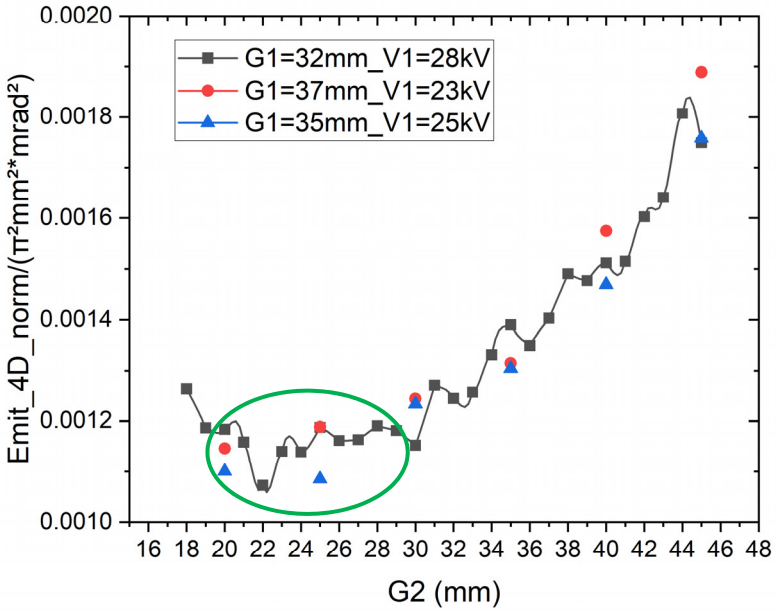


$$\Delta V^{3/2}/G1^2 \approx 0.25$$

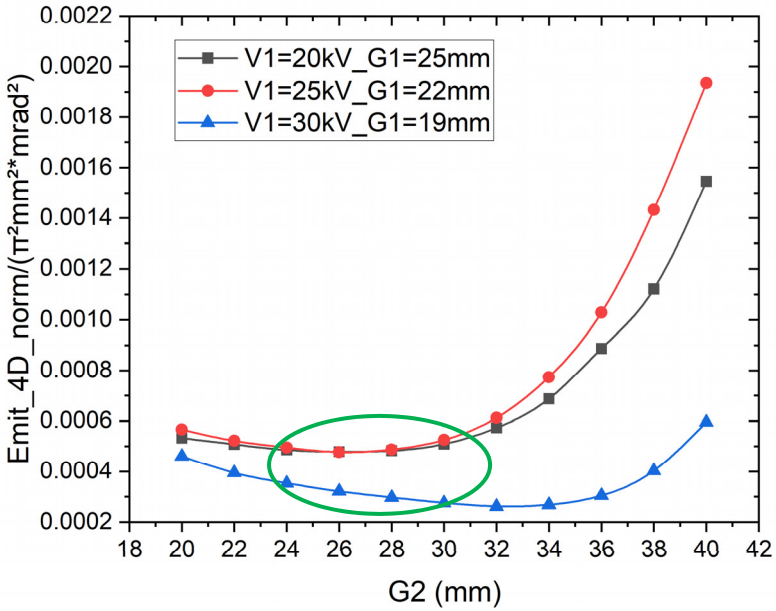
$$k \approx 2.14 \times 10^{-6} P$$

k: Optimal Generalized Perveance

Optimizing G2



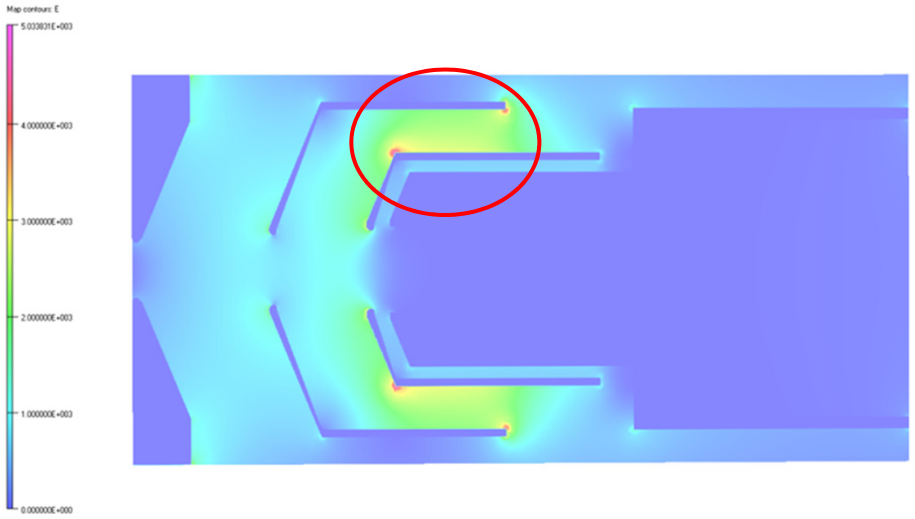
U^{35+}



O^{6+}

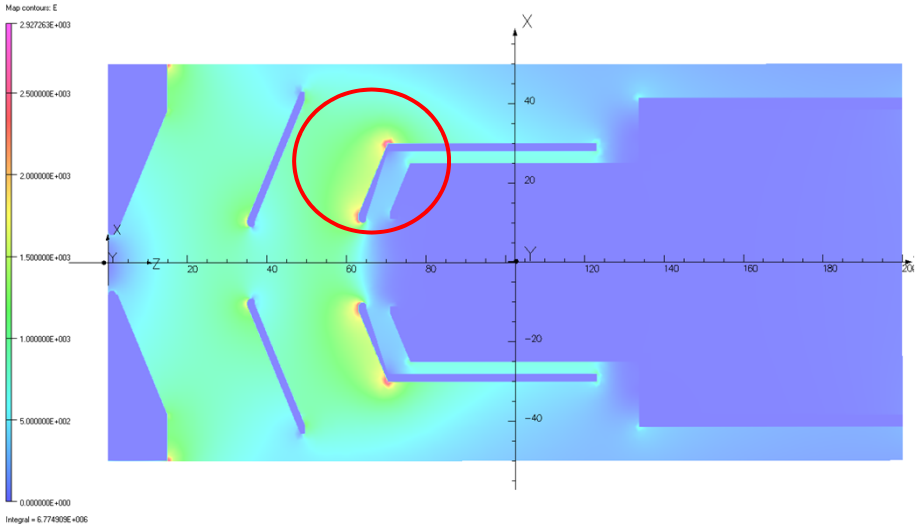
TOSCA: Electric Field Analysis

G1=35mm V1=25kV G2=25mm G3=6mm



Emax≈5.0kV/mm

G1=35mm V1=25kV G2=28mm G3=8mm

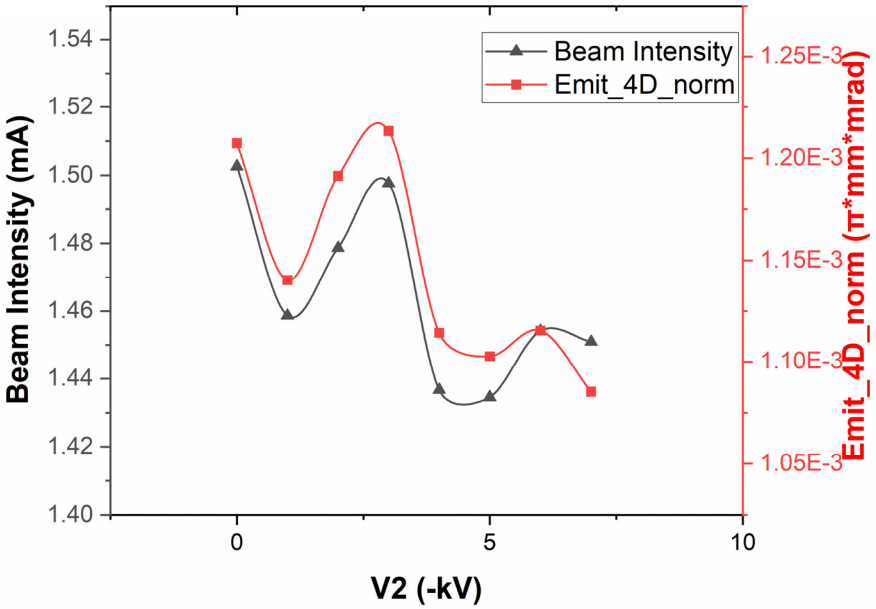


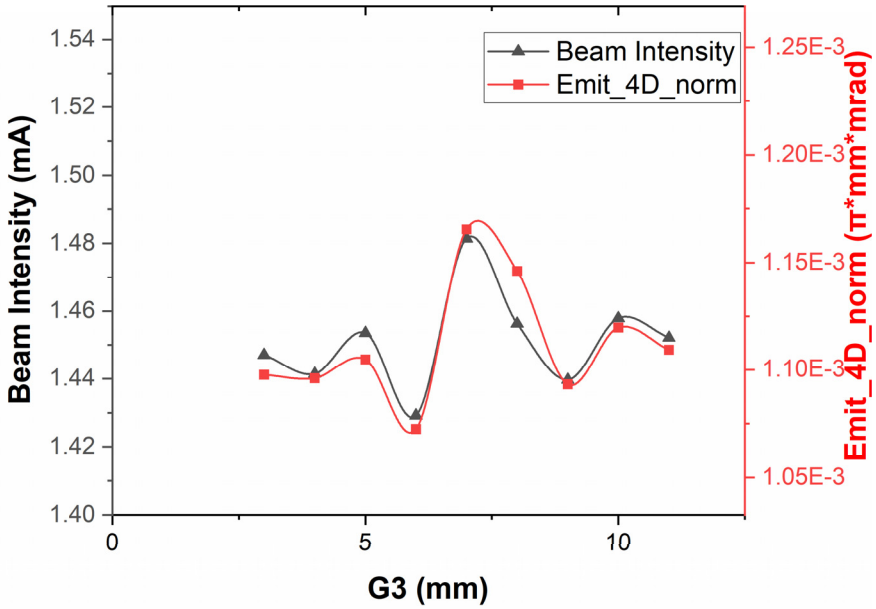
Emax≈2.9kV/mm

Conclusion

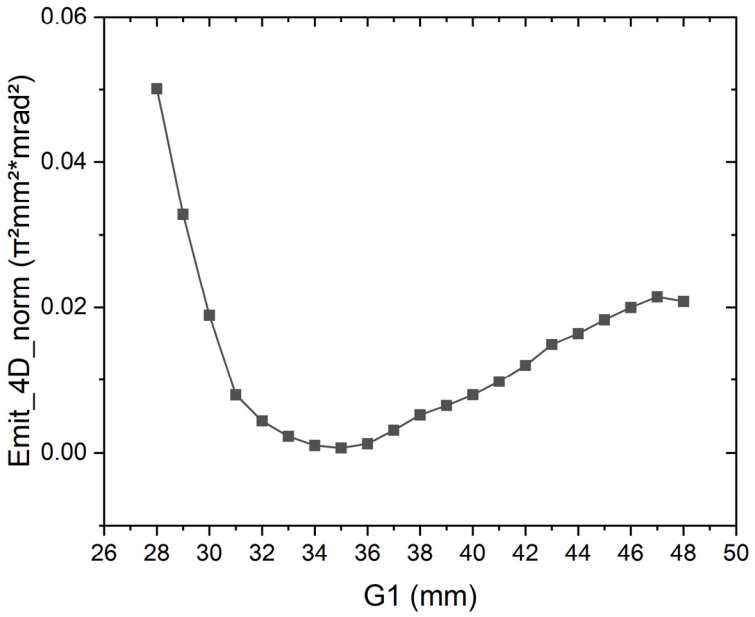
- The G1 & V1 are the most important parameters for the extracted beam quality, the k in equation $j_{opt} = \frac{k}{9\pi G1^2}(\frac{Z}{A})^{\frac{1}{2}}\Delta V1^{3/2}$ of this extraction system is about 2.19μP
- The optimal G2 is between 24~28mm (can be fixed)
- V2 & G3 have less influence on the beam quality than other parameters
- Disruptive discharge and Penning discharge are considered carefully

Appendix: U Beam V2&G3

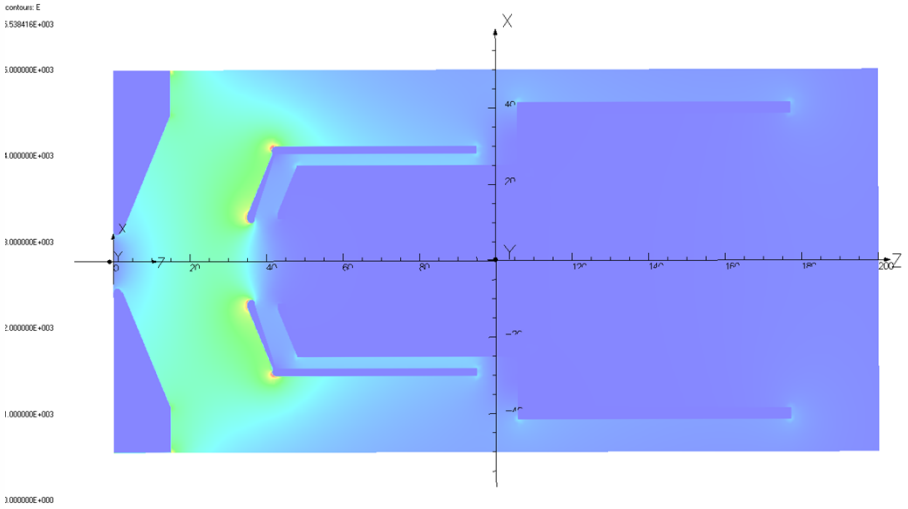




Appendix: 3-electrode for O Beam



G1=35mm



Emax≈5.5kV/mm