E-CLOUD Build-up in Grooved Chambers

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Outline of work

- Augment existing version of POSINST to model e-cloud build-up in the presence of grooved walls
  - Electron orbits are properly followed and collisions located on the groove surface where they occur but …
  - … when solving the Poisson equation for the electron self-field the boundaries are those of the smooth chamber (field enhancement at the groove edges not accounted)

- Features implemented so far:
  - Rectangular chamber cross section
  - Grooves are placed on top and bottom of wall
  - (Isosceles) triangular grooves with option to account for rounded tips

- Motivations:
  - Characterization of e-cloud dynamics more from ‘first principles’ instead of passing through an intermediate calculation of an ‘effective’ secondary yield for the grooved wall.
  - Validate previous calculations by M.Pivi, G. Stupakov, and L.Wang.
  - Help settle some alleged disagreement with other calculations
  - Provide modeling tools for ongoing and future measurements

Calculations done so far:

- Parameter choice specific for the ILC-DR dipoles.
  - Input deck for POSINST provided by M.Pivi with setting used for previous smooth-chamber DR simulations
- Exploration of dependence of e-cloud build up on:
  - Groove angle and height
  - Radius of the rounded groove tips
  - Magnitude of magnetic field
- Contact with previous calculations by extracting and effective SEY (*by comparison with e-cloud build-up curves for smooth chambers*)

ILC DR basic parameters used in simulations

Beam/dipole parameters:

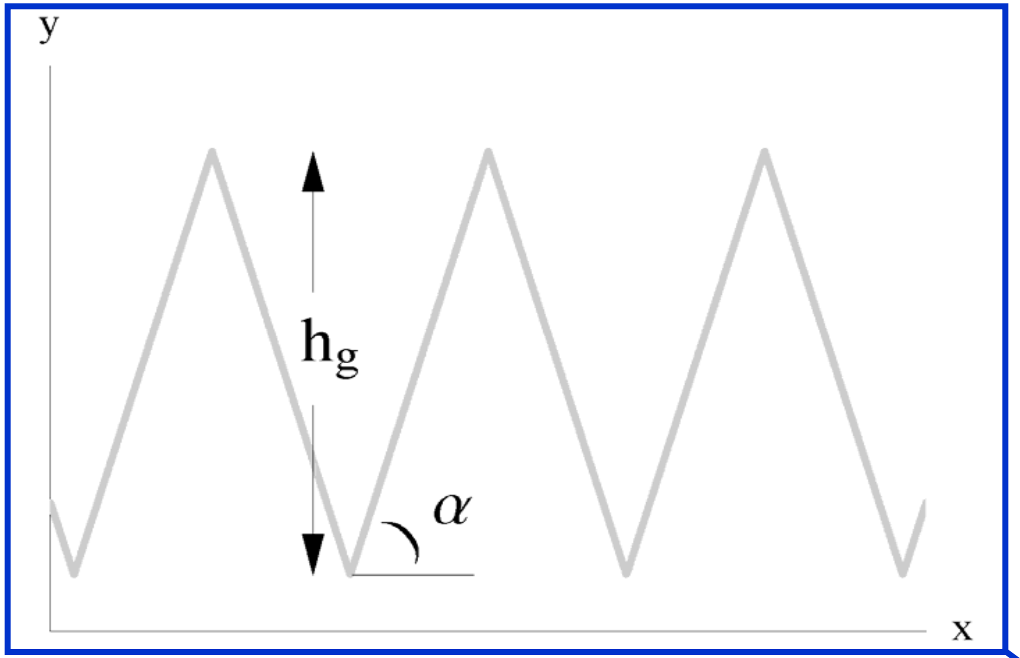
Dipole magnetic field	0.194 T
Beam sizes in bends	σ_x=0.62 mm, σ_y=8μm, σ_z=6mm
Particle/bunch	N=2*10^{10}

Bunch-train structure parameters:

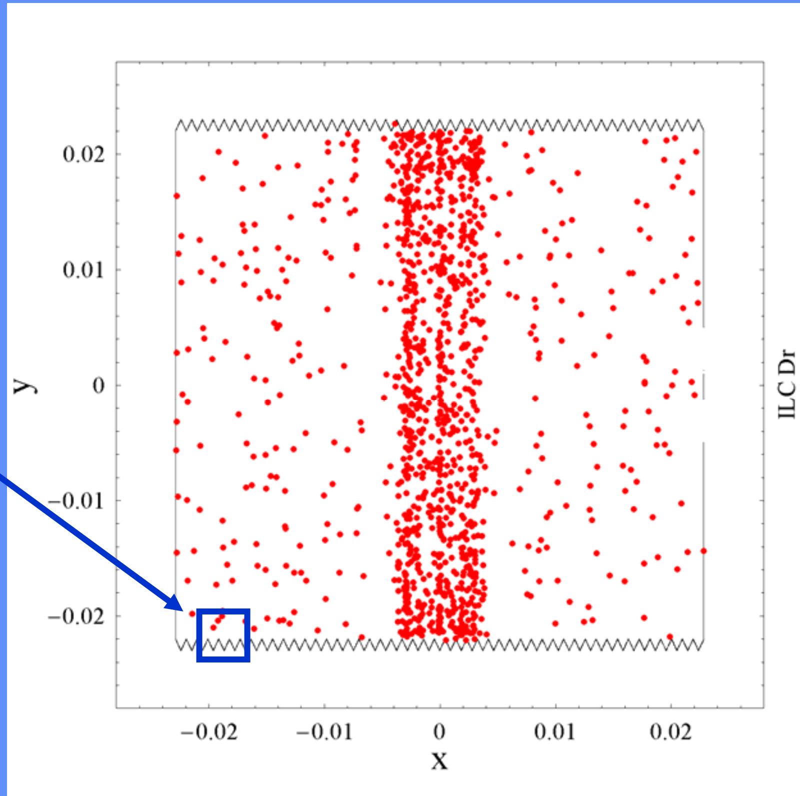
RF bucket spacing	1.52 ns (=0.46m) *[f_{RF}=650 MHz, C=6.11Km]*
Bunch spacing	6.1 ns (one every four RF buckets)
No. bunches/train	111
Train length	0.68 μs (=204m)

- Chamber sizes: 2.3*2.3 cm (rectangular)
- Max SEY (for smooth surface) **δ = 1.75**
- Max. no. of macro-e = 20K found to be adequate (i.e. get small noise in longitudinal e-density)

Geometry of triangular grooves



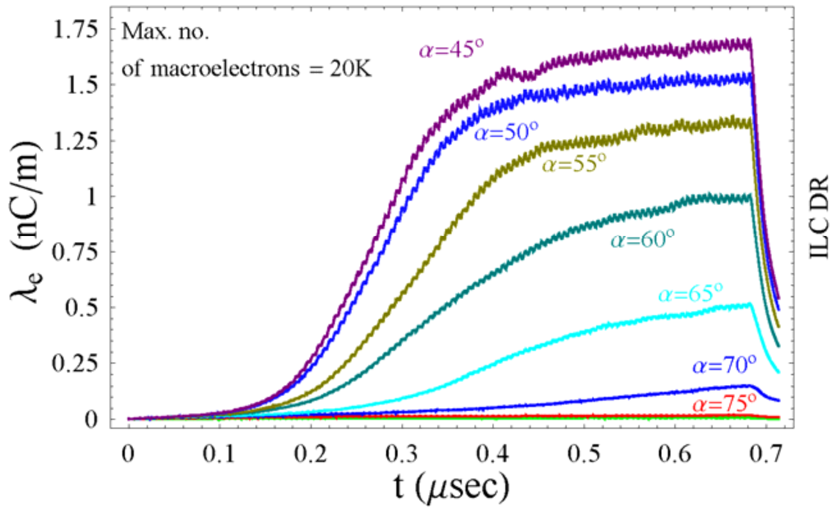
Snapshot of macro-electron distribution in chamber w/ grooves



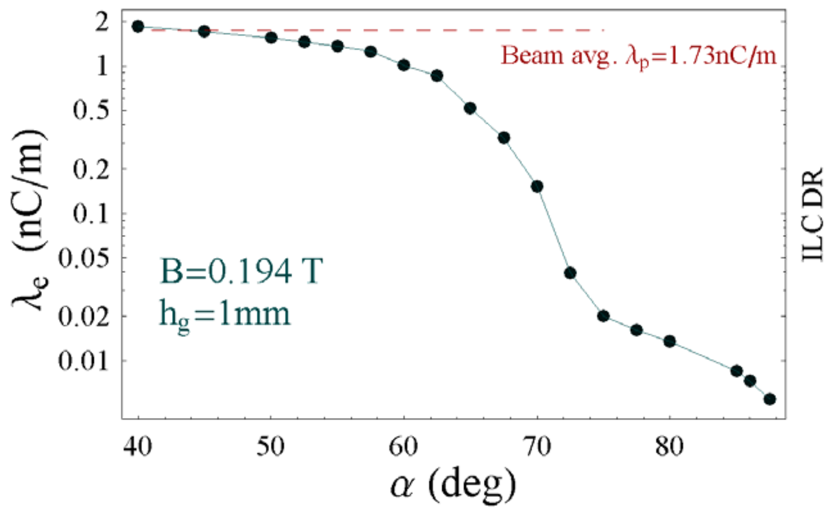
- Geometry of triangular grooves is defined by angle α and height h_g
- $\alpha=0^o$ == flat surface

E-cloud dependence on groove angle

E-cloud build-up during bunch-train passage for various α



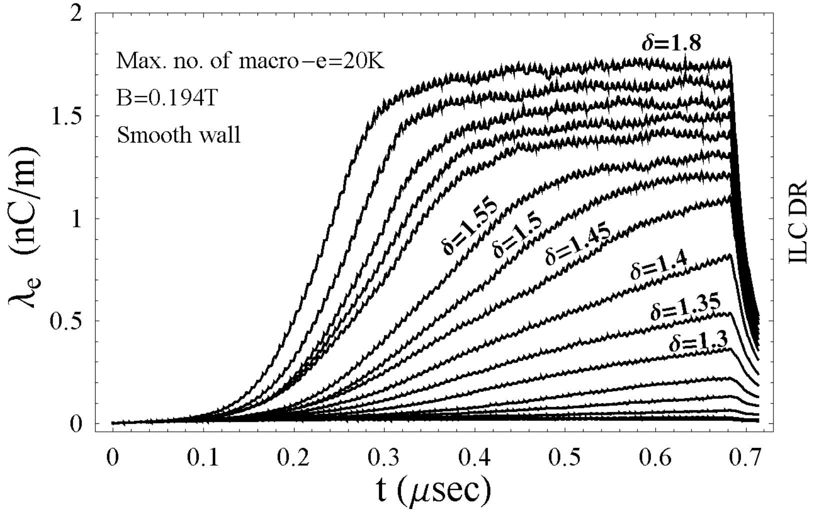
Max e-cloud density during bunch-train passage vs. α



- E-cloud density suppressed by a factor ~200 for groove angles $\alpha > 75^o$

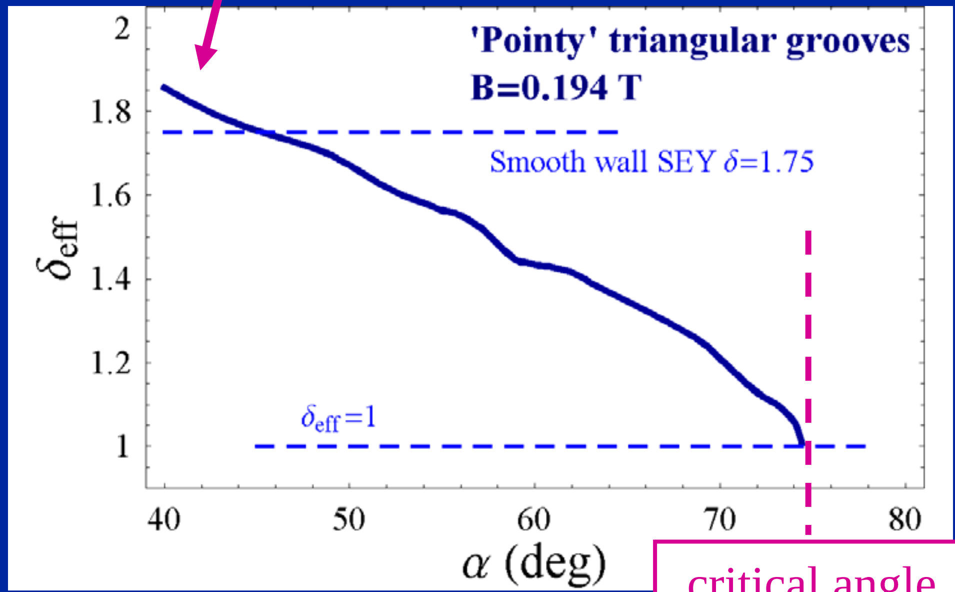
Extract an effective SEY from comparison with data from smooth chamber

E-cloud build-up during bunch-train passage for smooth walls, various max SEY δ



Shallow grooves increase yield!

Effective SEY δ for various groove angles

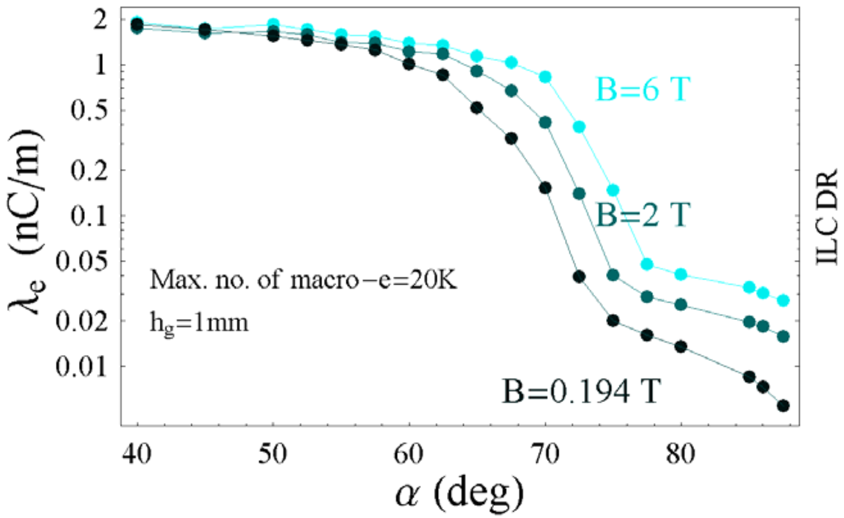


critical angle α~75^o

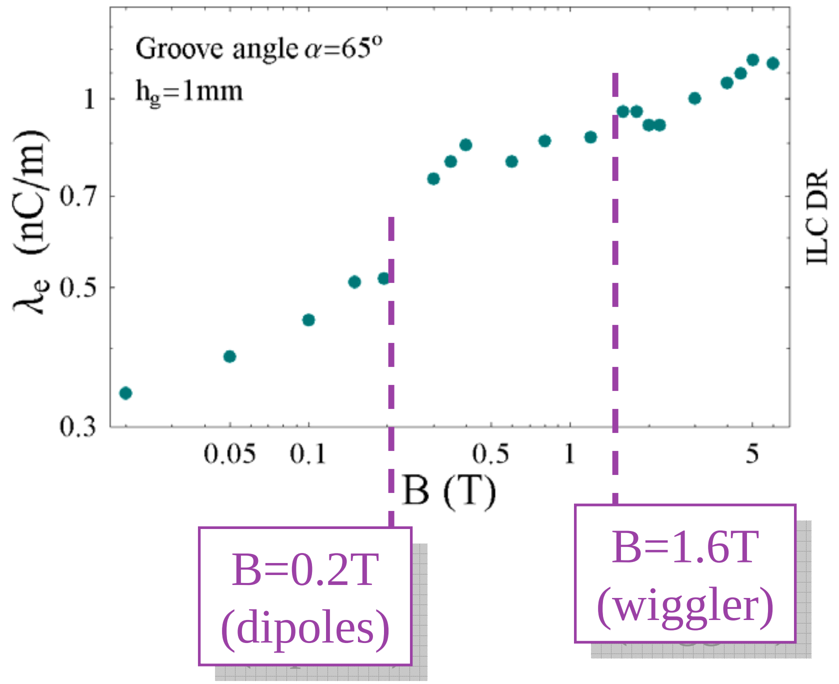
- The effective SEY for surface with groove angle α is defined as the SEY of a smooth chamber that results in the same max of e-cloud accumulation

A higher B-field degrades e-cloud suppression

E-cloud build-up during bunch-train passage for various B



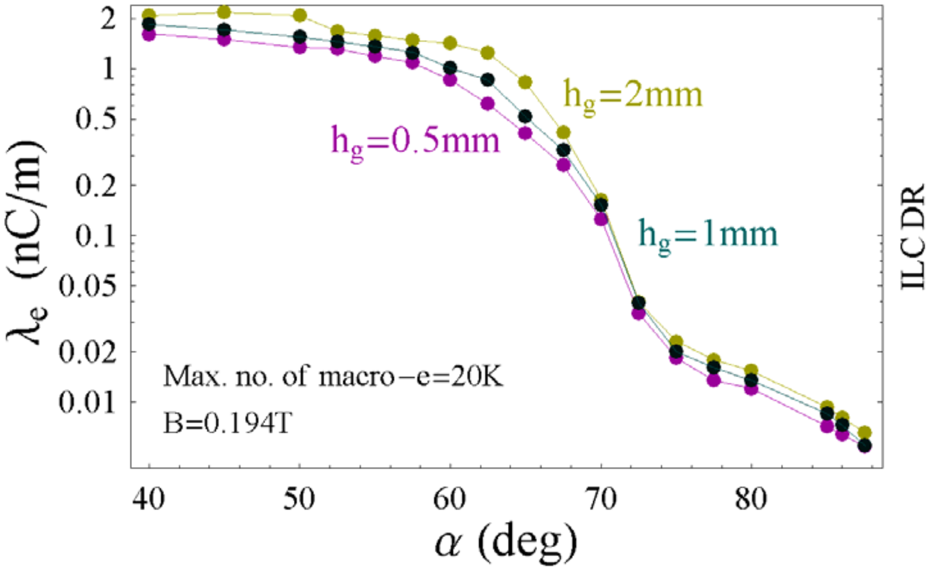
Max e-cloud density vs. B for fixed groove geometry



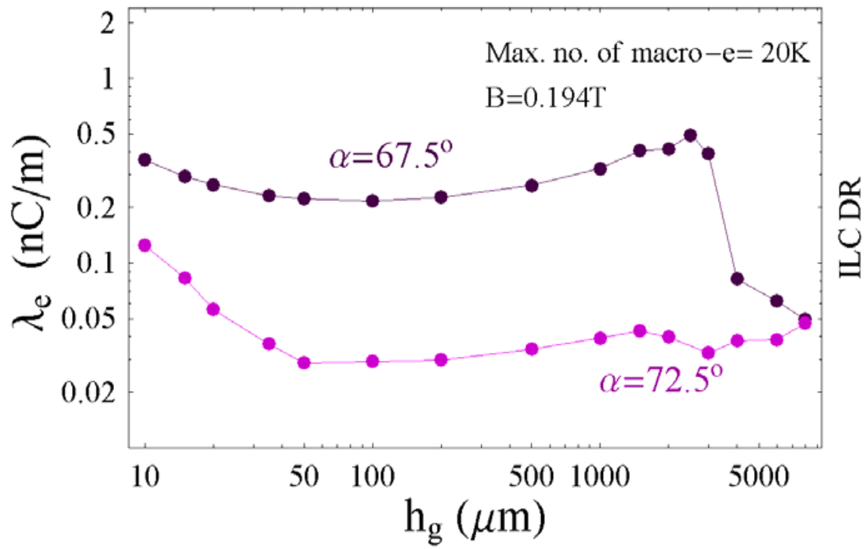
- A larger cyclotron radius (smaller B-field) enhances chance that secondary electrons may be promptly reabsorbed in wall collision

Dependence on groove height

Max of e-cloud density *vs.* groove angle α for three groove heights h_g



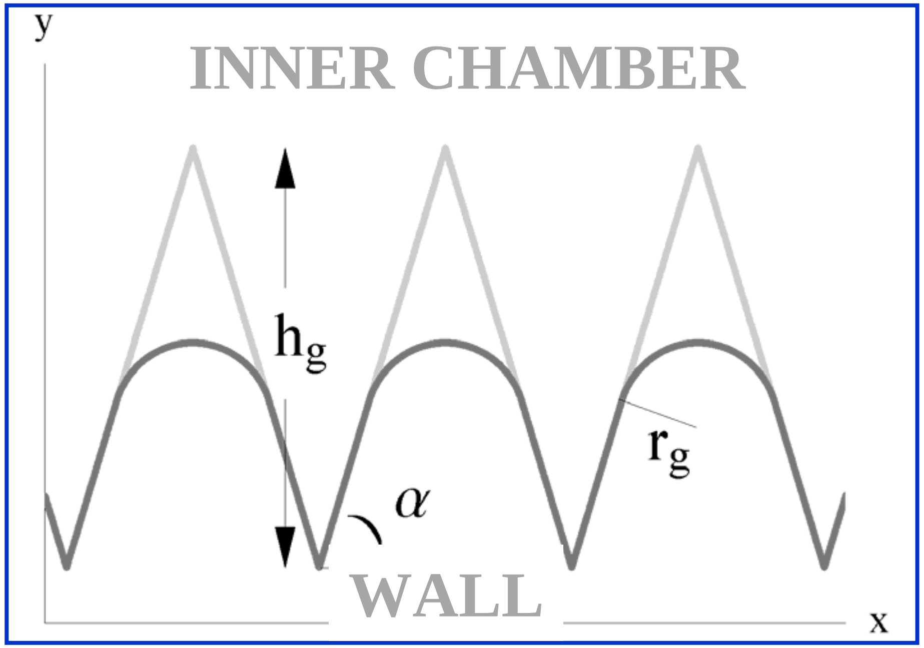
Max of e-cloud density *vs.* height h_g for two groove angles



- Dependence appears to be generally mild over a large span of height variations

Triangular grooves with smooth tips

- Smoothing groove tips may be desirable to ease impedance, manufacturing

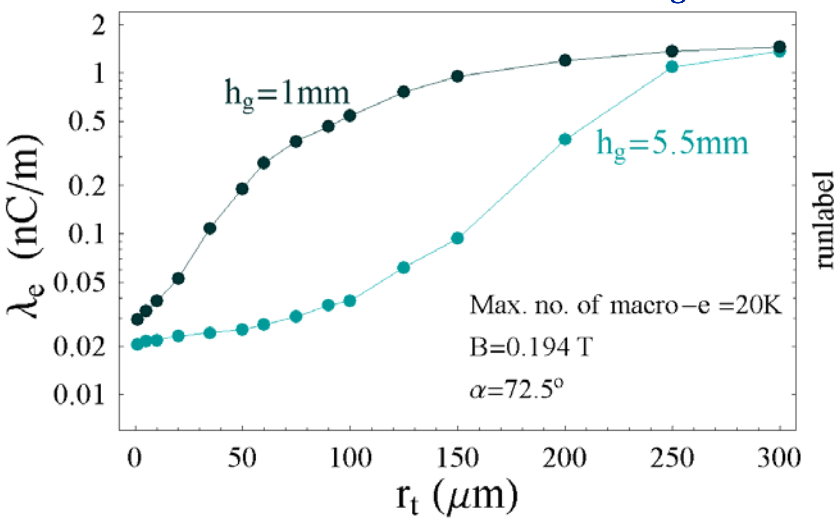


In present model only the groove edges on the chamber inner side are smoothened

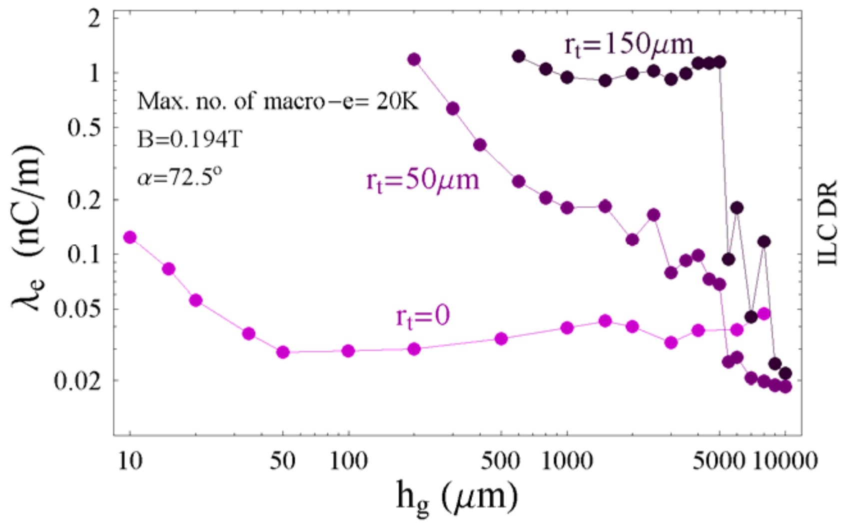
- Geometry of triangular grooves is defined by angle **α**, height $\mathbf{h_g}$, and tip radius $\mathbf{r_g}$

Smoother tips spoil effectiveness of grooves

Max of cloud density *vs.* groove-tip radius for two groove height h_g



Max of cloud density *vs.* height h_g for 3 choices of groove-tip radius



- Spoiling effect of smooth groove-tips can be compensated by making the grooves deeper.
- Finite groove-tip radius enhances dependence of groove effectiveness on groove height

Conclusions

- Isosceles triangular grooves with steepness angle $\alpha > 75^o$ reduce effective SEY to < 1
  - E-cloud build up for a 111 bunch train is reduced by a factor 200.
- Results seem about consistent with previous calculations by L.Wang (α ~70^o for effective SEY < 1, *SLAC-PUB-12001*)
- A larger magnetic field makes the grooving less effective.
  - In wigglers the groove angle likely to have to be steeper to provide same e-cloud suppression effect as in dipoles
- Rounding of the tips spoils e-cloud suppression, which can be compensated by deepening the grooves