Measuring Emittances with Crystals

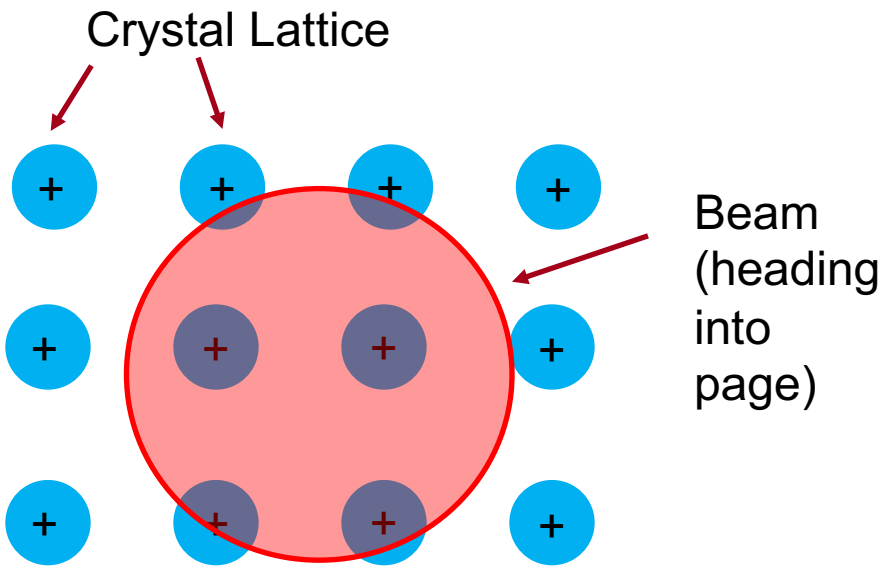
Brendan O'Shea

U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

How does Crystal Channeling work?

- Each crystal is cut so that along the beam direction the atoms line up.
- Close enough to the atoms the potential is attractive for electrons.
- Electrons with sufficiently small transverse velocity are trapped in the potential.



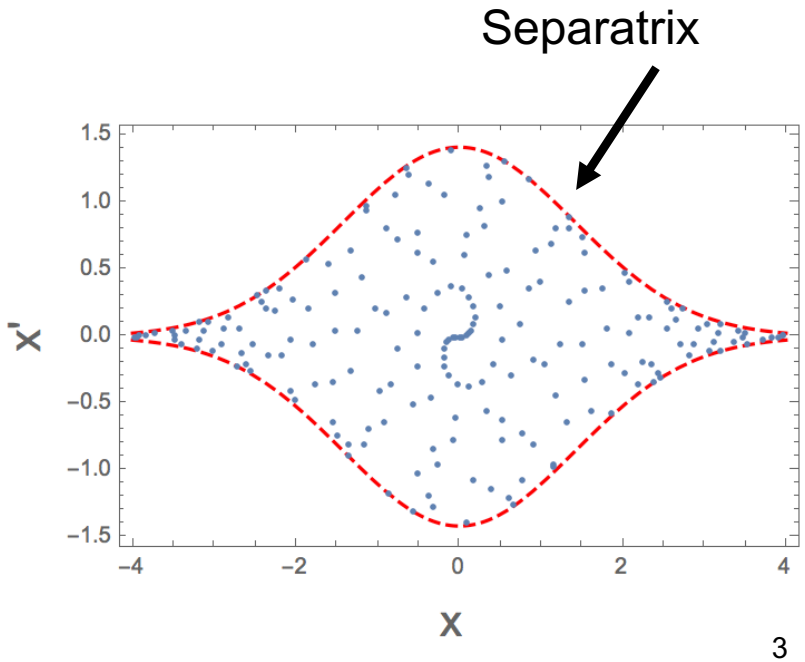
Crystal Math

- Potential modeled as a Gaussian shape
- Critical angle ψ_c parameterizes acceptance of crystal channel
- Beta functions for each beam are assumed matched to the plasma, $\lambda_p = 100\,\mu m$

$$U(x) = U_0\left(1 - e^{-\frac{x^2}{2a_0^2}}\right)$$

$$H_x = \frac{p^2\psi^2}{2\gamma m} + U(x)$$

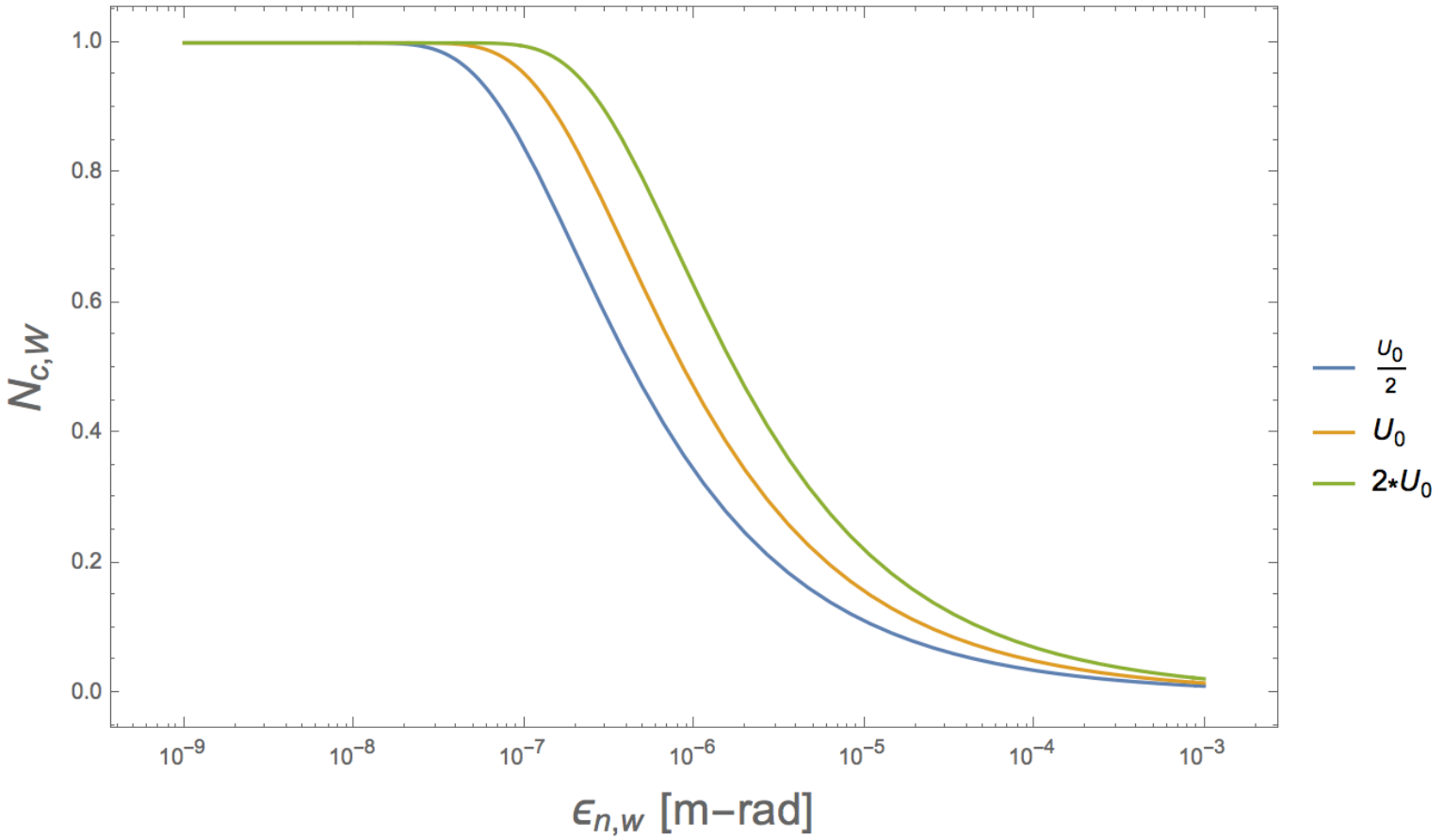
$$\psi_c^2 = \frac{2U_0}{\gamma mc^2}$$



	ϵ_N [μm]	Energy [GeV]
Drive	10^{-5}	10
Witness	10^{-8}	1

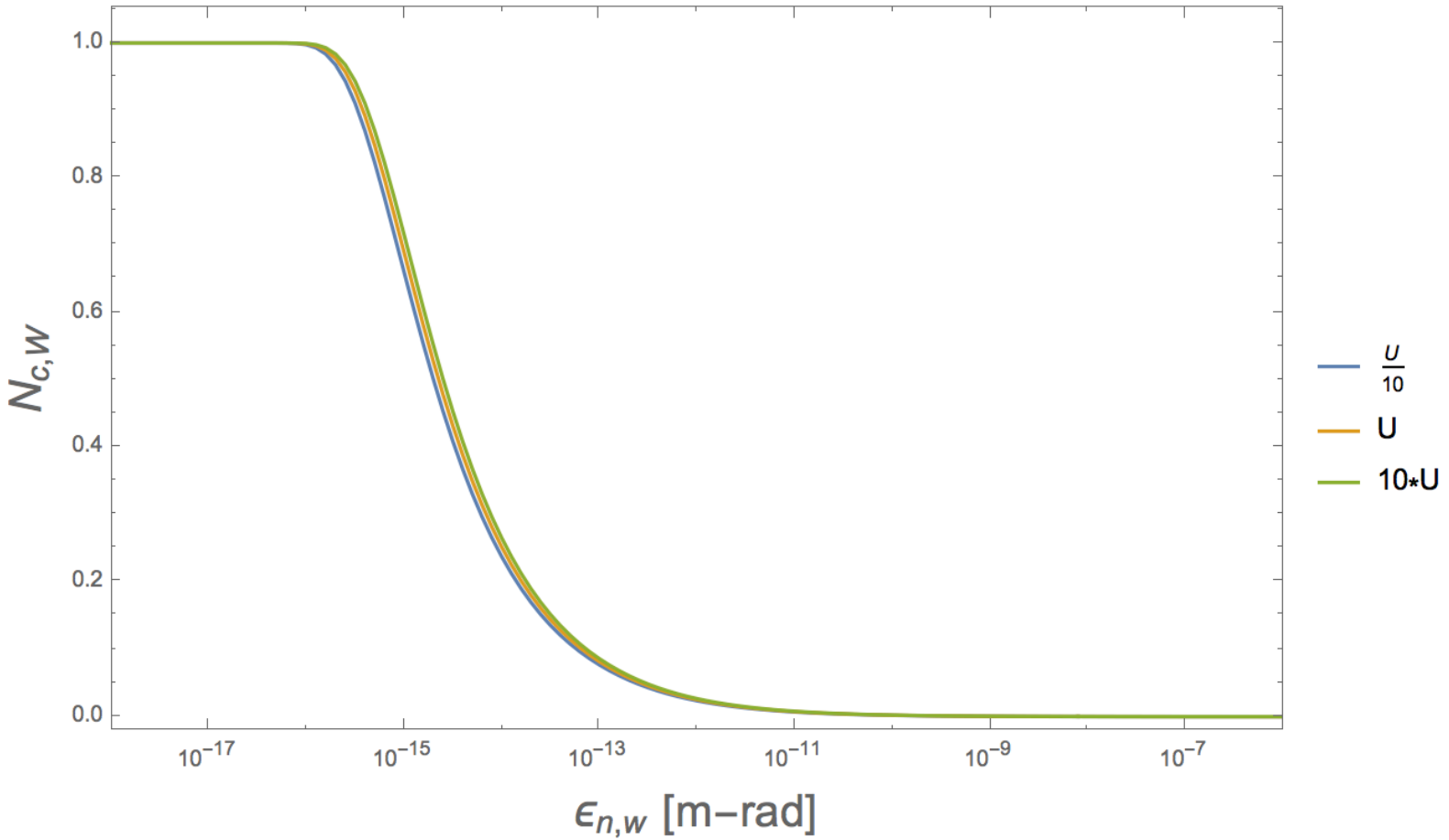
Acceptance Ignoring the Spatial Dimension

$$N_c = \frac{1}{\sqrt{2\pi}\sigma_{x'}} \int_{-\psi_c}^{\psi_c} e^{-\frac{x'^2}{2\sigma_{x'}^2}} d\,x' = Erf[\frac{\psi_c}{\sqrt{2}\sigma_{x'}}]$$

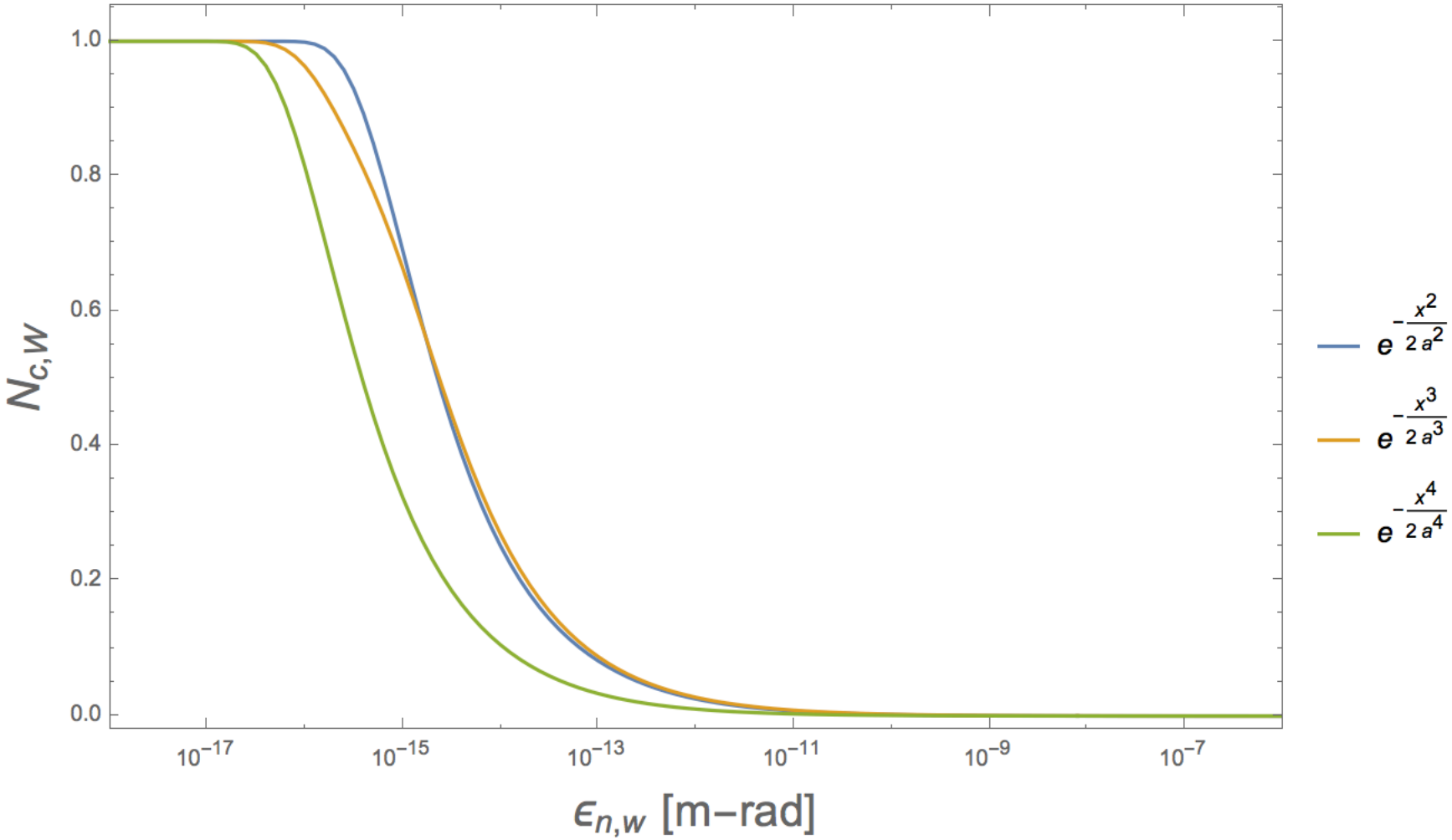


A single potential well

$$N_c = \frac{1}{2\pi\sigma_{x'}\sigma_x}\int_{-\infty}^{\infty} dx \int_{-\psi_c e^{-\frac{x^2}{4a_0^2}}}^{\psi_c e^{-\frac{x^2}{4a_0^2}}} e^{-\frac{(x-x'z)^2}{2\sigma_x^2}} e^{-\frac{x'^2}{2\sigma_{x'}^2}} d\,x'$$



A single potential well, part deux

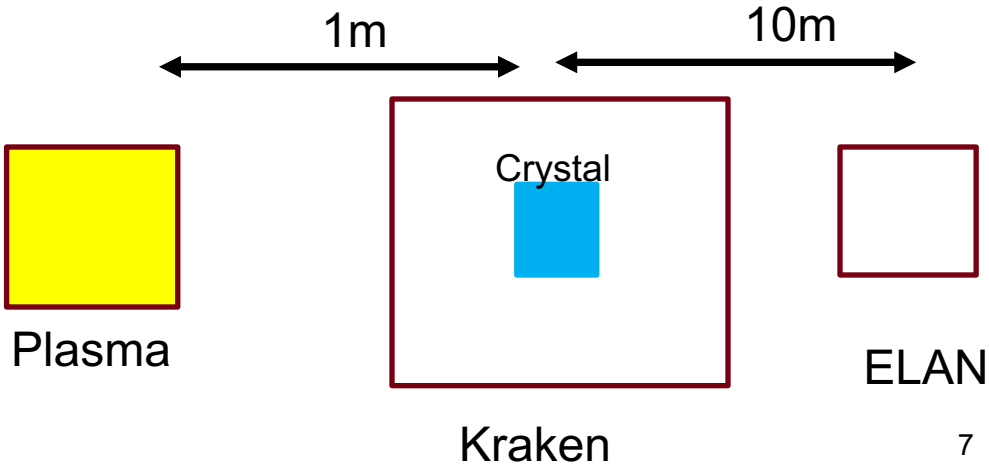


Challenges

- Negative particles tend to hit the string, causing de-channeling $n = n_0 e^{-\frac{z}{L_d}}$
  - L_d~40 μm
- Have to get angle correct for beam size:
  - Ex: β=0.5m,ϵ_n=10^{-8},γ =2*10^3
  - σ_x=1mm @ELAN
  - Crystal bend of 300 μ rad->3mm
- Crystal Length ~40 μ m

Relative intensities: • ≥ 2, / ≥ 3, W ≥ 4, x ≥ 5, ▼ ≥ 6, ■ ≥ 7

Fig. 7. 15 GeV/c π^- incident on a 4.2 mm Ge single crystal. Same plot and condition as in fig. 6. Here planar effects are absent but there is a peak in the axial direction surrounded by a low-intensity region. Note that the axial peak is lower than the random "plateau" far from the axis. There are 10 000 events in the plot.



Summary

- To Understand:
- Shape of the potential
- Beam transfer from plasma to vacuum and distance from plasma to crystal
- Effect of beam on crystal
  - string re-ordering due to temperature
  - string damage
- A better understanding of electron-string collisions