

# SCATTERING OF 255 MEV ELECTRONS AT (220) CHANNELING IN SILICON CRYSTAL

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## Motivation

- ❑ The angular and spatial distributions of 255 MeV electrons at  $\langle 100 \rangle$  axial channeling in a thin silicon crystal have been investigated recently experimentally (at SAGA Light Source) and by computer simulations (O. V. Bogdanov, Yu. L. Pivovarov, Y. Takabayashi, T. A. Tukhfatullin, J. of Phys.: Conf. Ser. 357 (2012) 012030)
- ❑ Both experimental data and simulations show the brilliant effect of so-called “doughnut scattering” (DS) that can be used e.g. for diagnostics of the incident beam angular divergence. (U. Uggerhoj, The interaction of relativistic particles with strong crystalline field, NIMB, 252, 2006, 16-19)
- ❑ Recently, the new experiment on 255 MeV electron scattering at (220) planar channeling in a 20  $\mu\text{m}$  Si crystal was carried out at SAGA LS.
- ❑ This report: analysis & discussion of spatial and angular distributions of 255 MeV electrons penetrating through a 20  $\mu\text{m}$  Si crystal at (220) alignment - experimental data vs computer simulations

# SAGA Light Source (SAGA-LS)

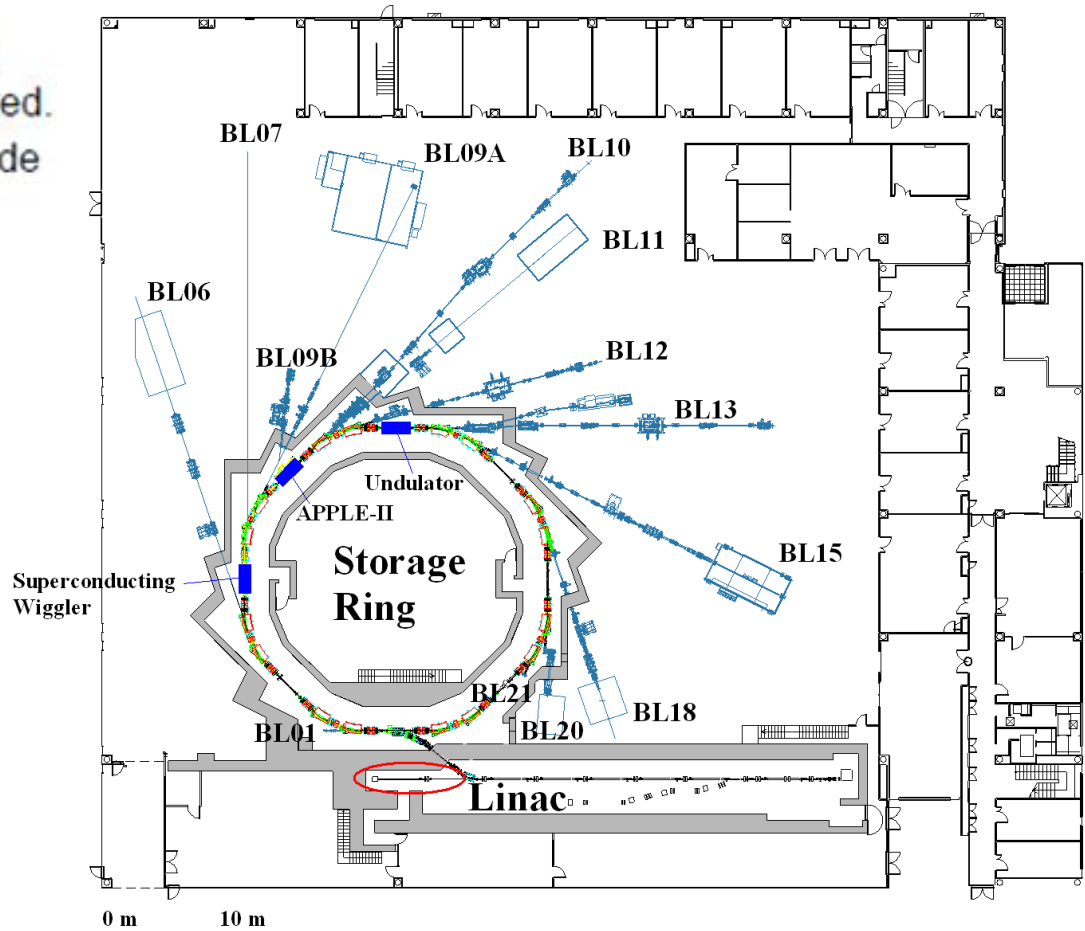
Operated by Saga Prefecture in Japan  
 In 2004, the accelerators were completed.  
 In 2006, the SAGA-LS started user-mode operation.

## Storage Ring

Circumference	75.6 m
Energy	1.4 GeV
Stored Current	300 mA
Emittance	25 nm-rad
Lifetime	~7 hours @300 mA
Critical Energy	1.9 keV

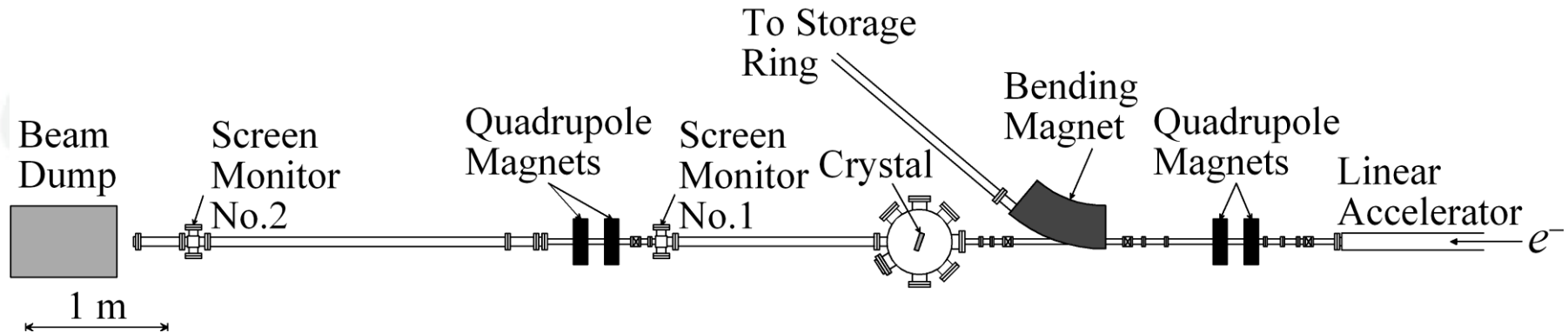
## Injector Linac

Total Length	30 m
Energy	255 MeV
Average Current	12 nA
Repetition	1 pps



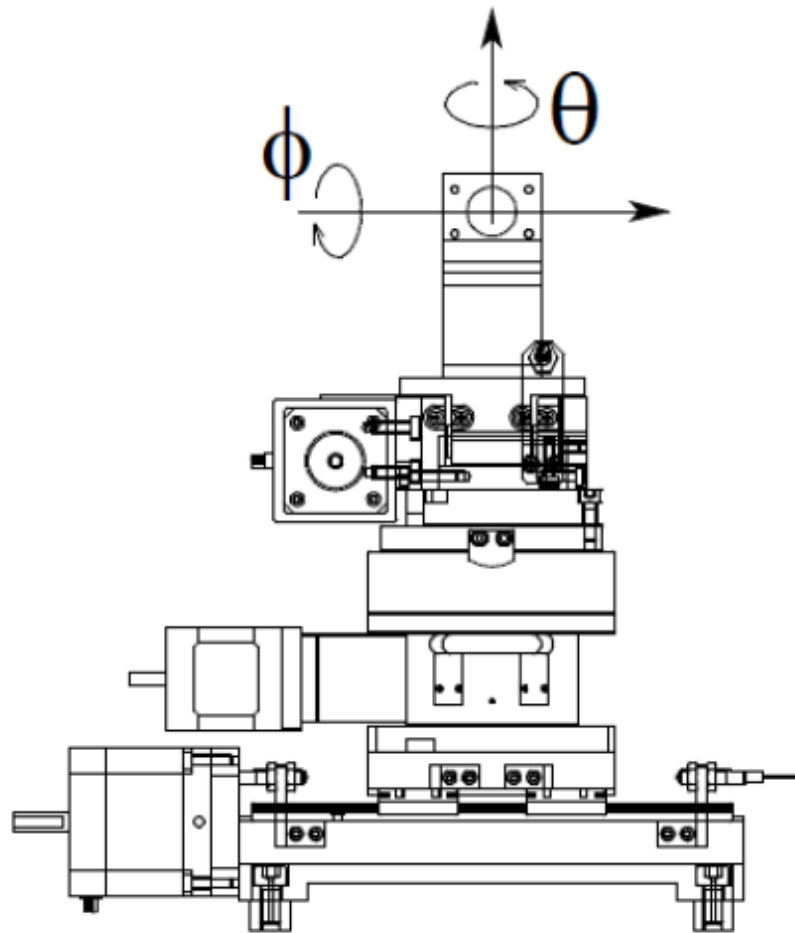
**SAGA Light Source, 8-7 Yayoigaoka, Tosu, Saga 841-0005, Japan**

# Channelling Experiments at SAGA-LS



- (220) channeling of 255 MeV  $e^-$  in 20- $\mu\text{m}$ -thick Si crystal
- Beam sizes at the crystal:  
 $\sigma_x \cong 0.3 \text{ mm}$  (horizontal) and  $\sigma_y \cong 0.9 \text{ mm}$  (vertical)
- Angular divergences of the incident beam at the crystal:  
 $\sigma'_x \cong 0.1 \text{ mrad}$  (horizontal) and  $\sigma'_y \cong 0.1 \text{ mrad}$  (vertical)
- The screen monitor No. 2 was used **at** the experiments.
- The distance from the crystal to the screen was  $L = 5.12 \text{ m}$ .

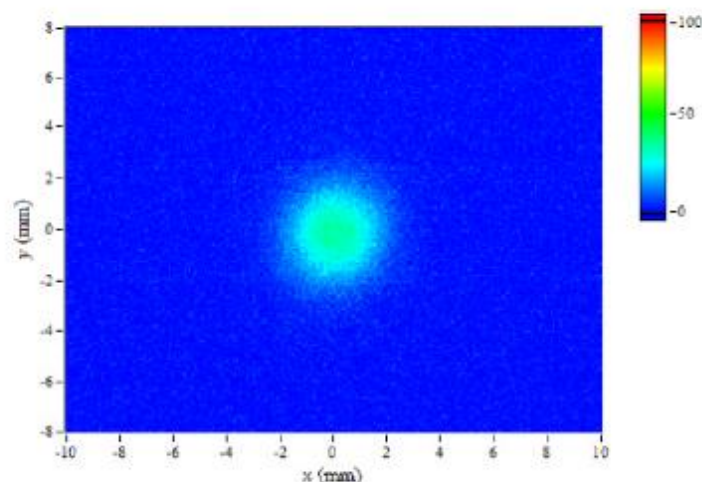
## Goniometer



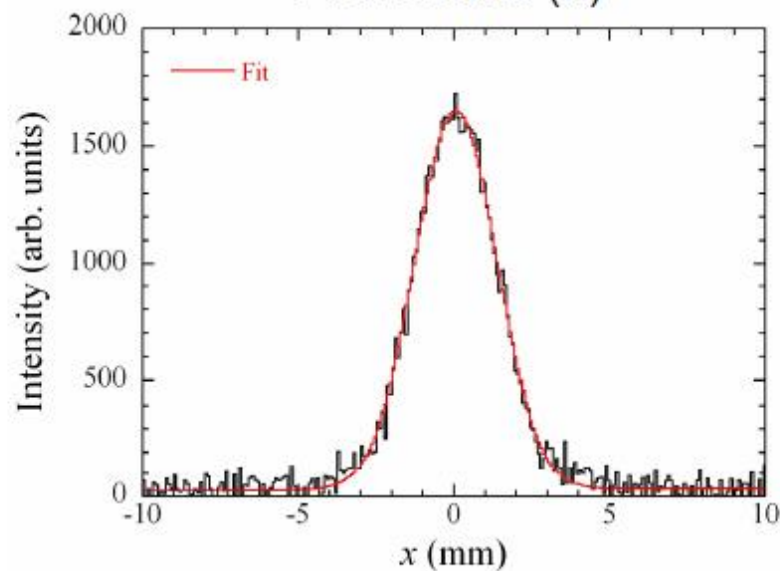
Angular step size **0.001°**

# Data Analysis

$$(\theta, \phi) = (0^\circ, 0^\circ)$$

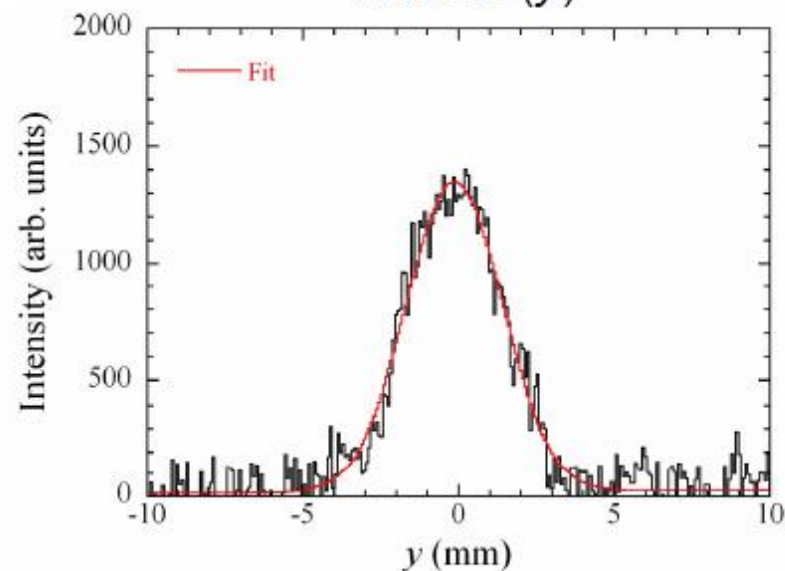


Horizontal (x)



$$I_x = I_{0,x} \exp\left[-\frac{(x - x_{peak})^2}{2\sigma_x^2}\right] + a_x x + b_x$$

Vertical (y)

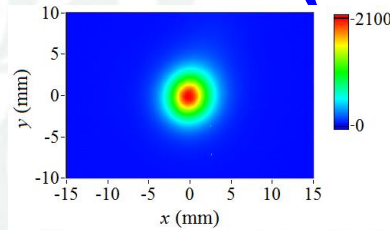


$$I_y = I_{0,y} \exp\left[-\frac{(y - y_{peak})^2}{2\sigma_y^2}\right] + a_y y + b_y$$

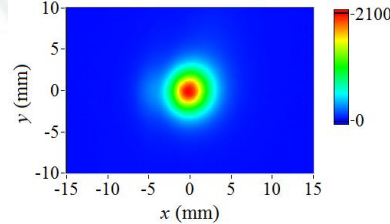


# The experimental results for (220) channeling in Si

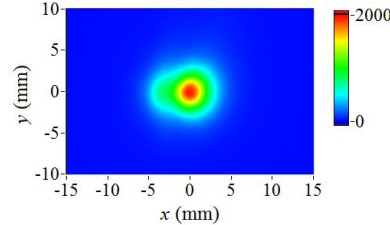
$(\theta, \phi)$   
 $(-0.10^\circ, 1^\circ)$



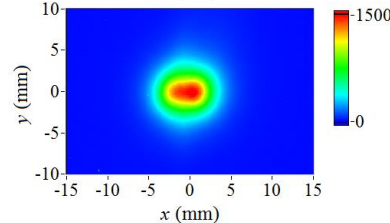
$(-0.05^\circ, 1^\circ)$



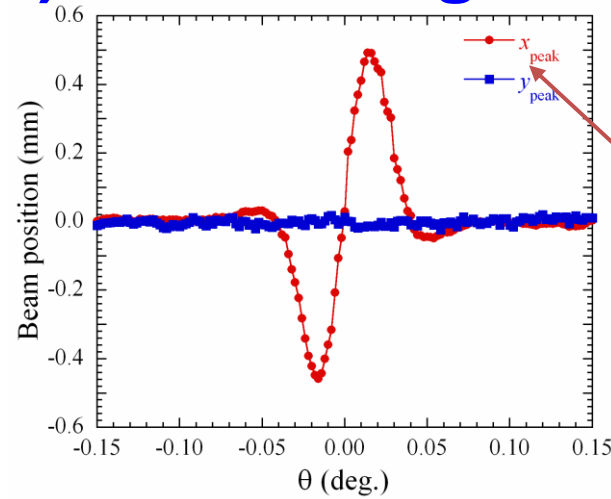
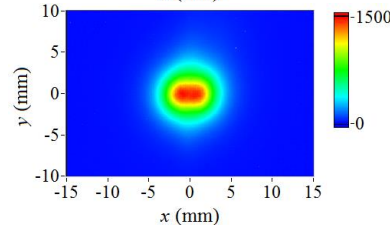
$(-0.03^\circ, 1^\circ)$



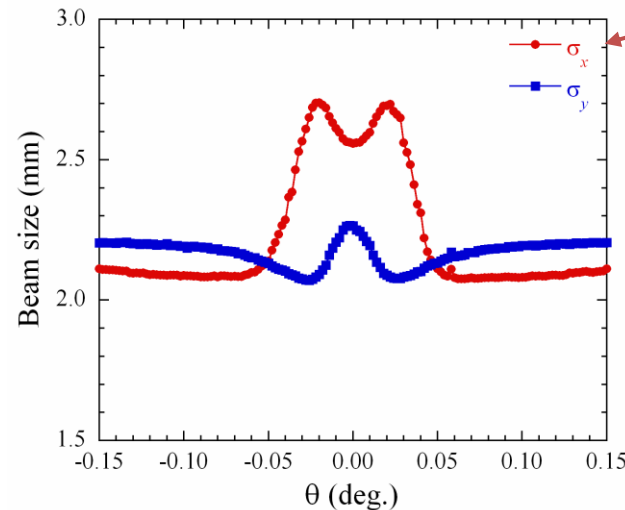
$(-0.01^\circ, 1^\circ)$



$(0^\circ, 1^\circ)$



$$I_x = I_{ox} \exp \left[ -\frac{(x - x_{peak})^2}{2\sigma_x} \right] + a_x x + b_x$$



## 255 MeV electrons → (220) Si trajectories simulation

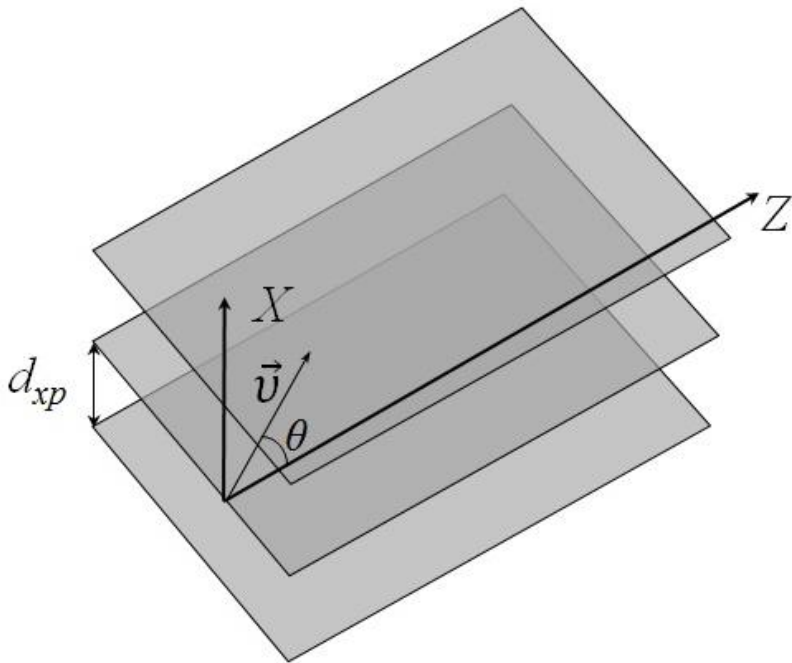
- Equation of motion

$$\gamma m \ddot{x} = F_x = -\frac{\partial U(x)}{\partial x}, \quad \gamma m \ddot{z} = 0$$

- Initial conditions

$$x(0) \equiv x_0$$

$$v_x(0) = c \sqrt{1 - \frac{1}{\gamma^2}} \sin(\theta)$$

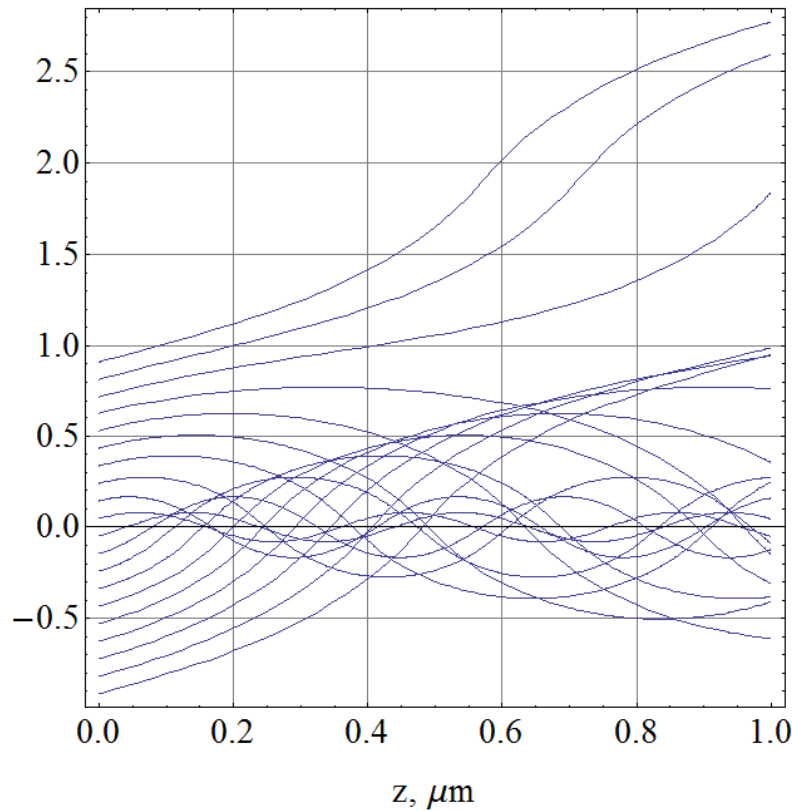


Bogdanov O. V., Fiks E. I., Korotchenko K. B., Pivovarov Yu. L. and  
Tukhfatullin T. A. Basic channeling with Mathematica©: A new computer code//  
J. Phys.: Conf. Ser. V. 236, 1, 2010, 012029

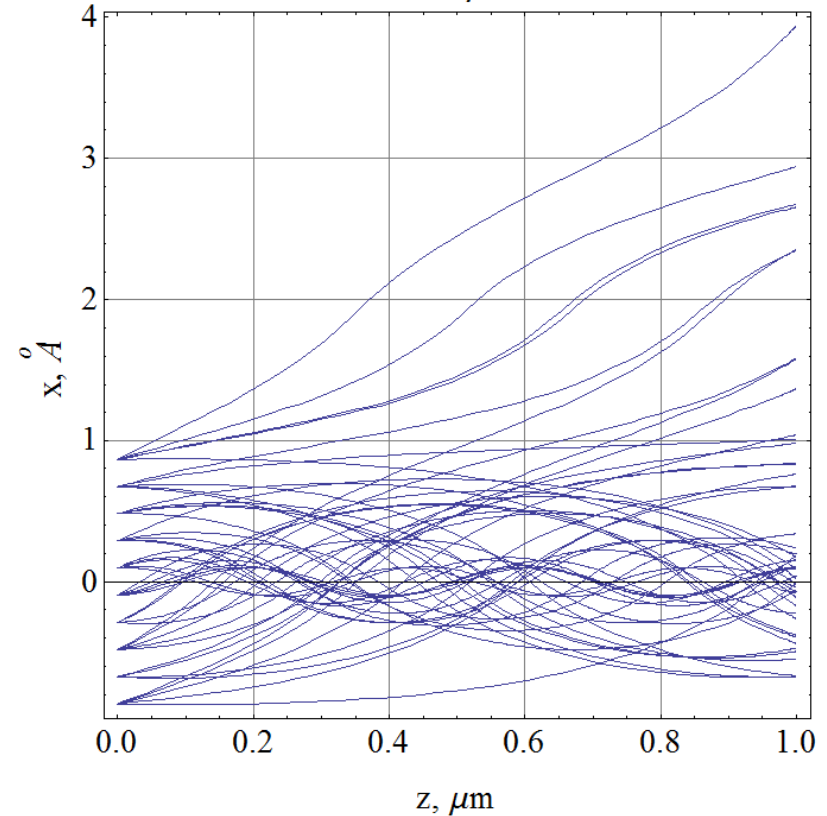


# Simulations: typical trajectories of (220) planar channelled 255 MeV electrons in Si

Electrons,  $L=1\text{ }\mu\text{m}$ ,  $\theta=0.005^\circ$

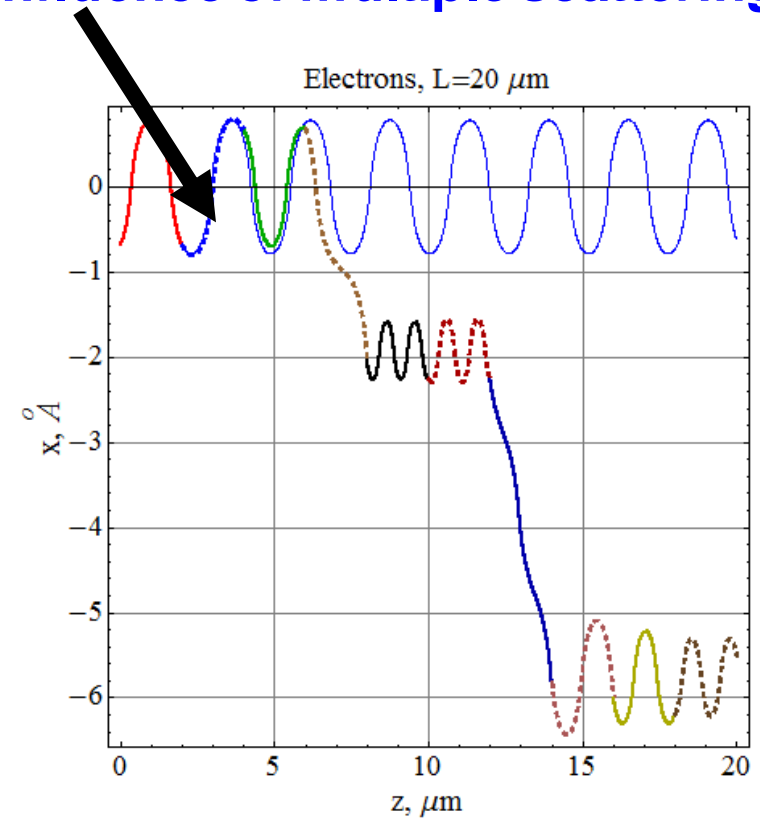
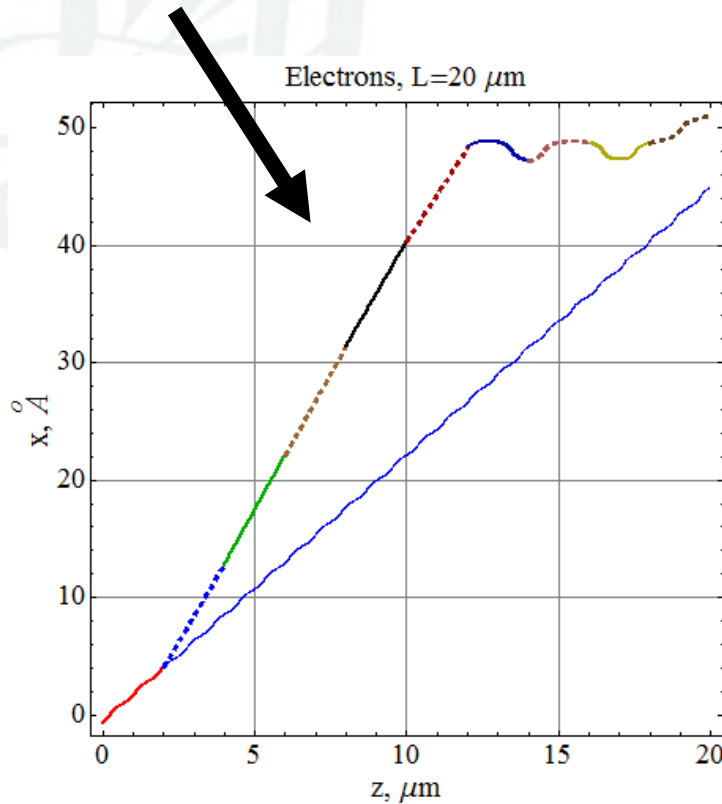


Electrons,  $L=1\text{ }\mu\text{m}$ ,  $\theta=0.005^\circ$



**Angular divergence**

# Simulations: 255 MeV $e^- \rightarrow \text{Si}$ Typical (220) trajectories in Si and influence of multiple scattering

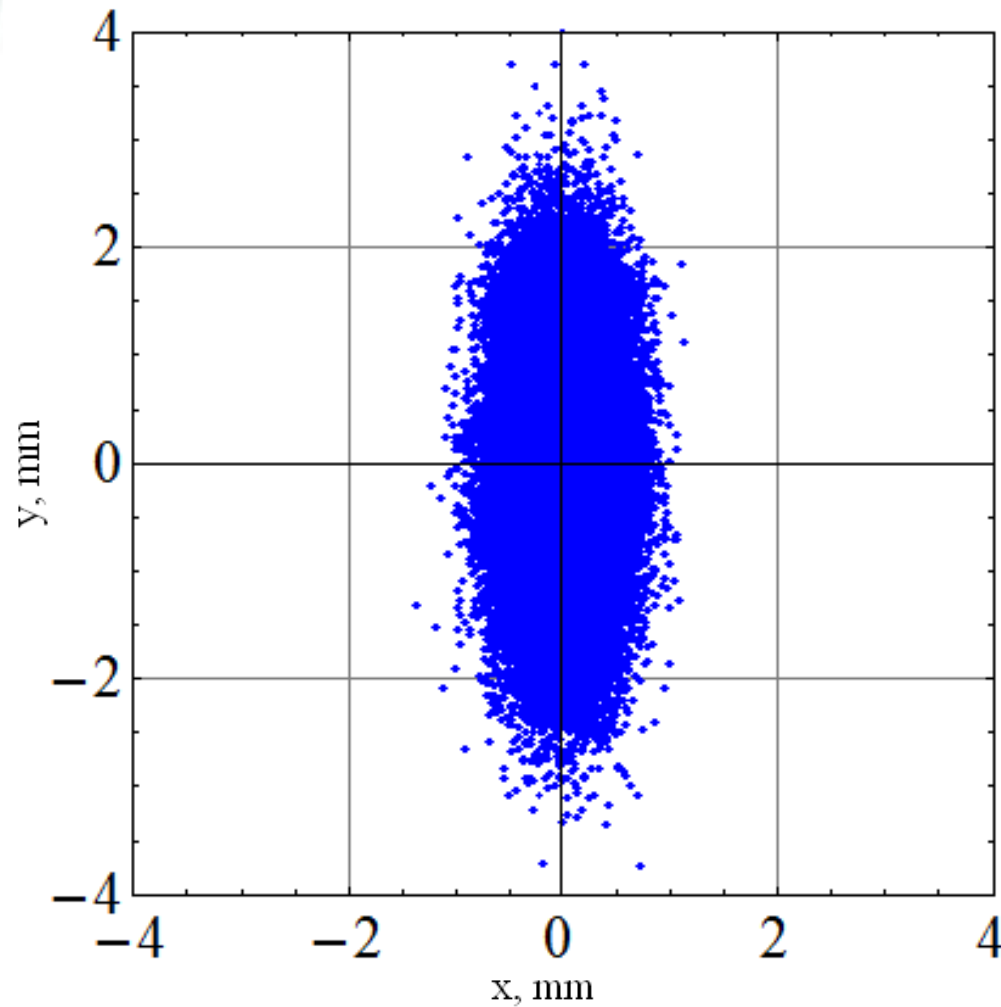


Solid line represents trajectory without addition

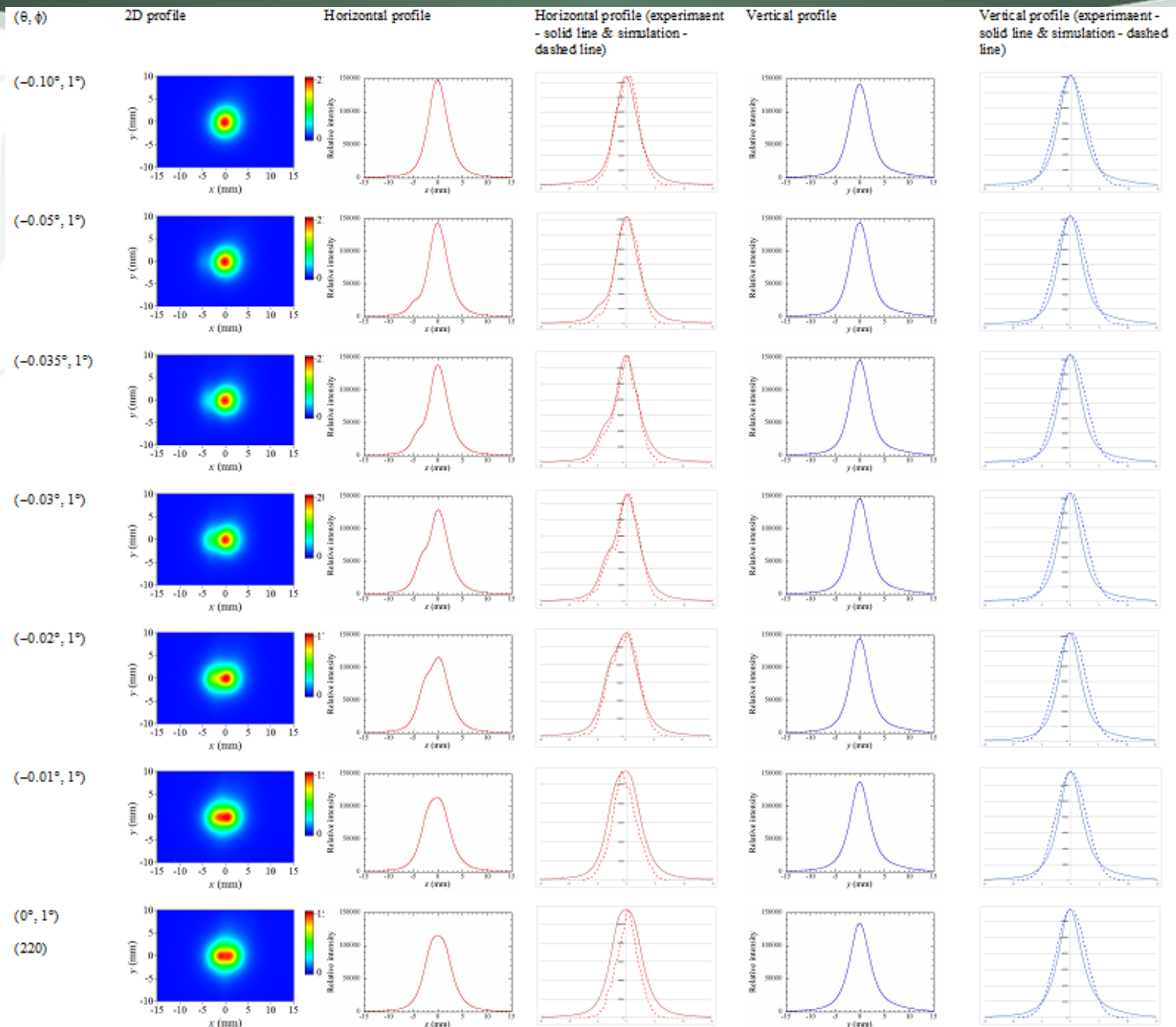
$L=2\mu\text{m}$   $\theta_{\text{ms}}=0.12 \text{ mrad}$

Review of Particle Physics. 2010.

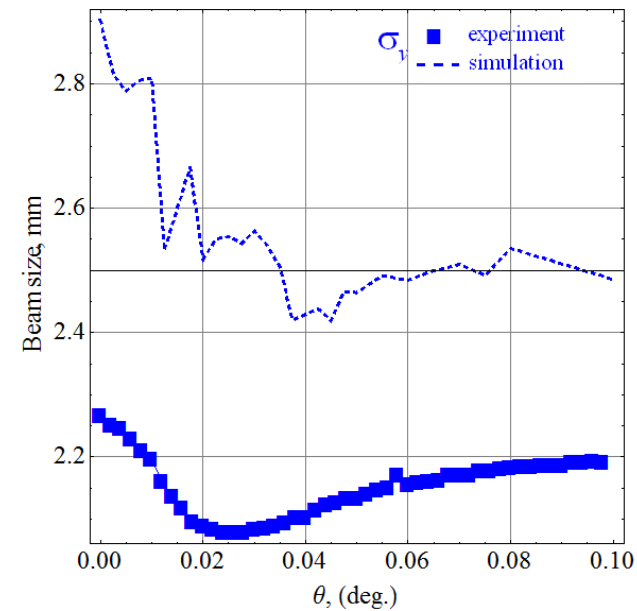
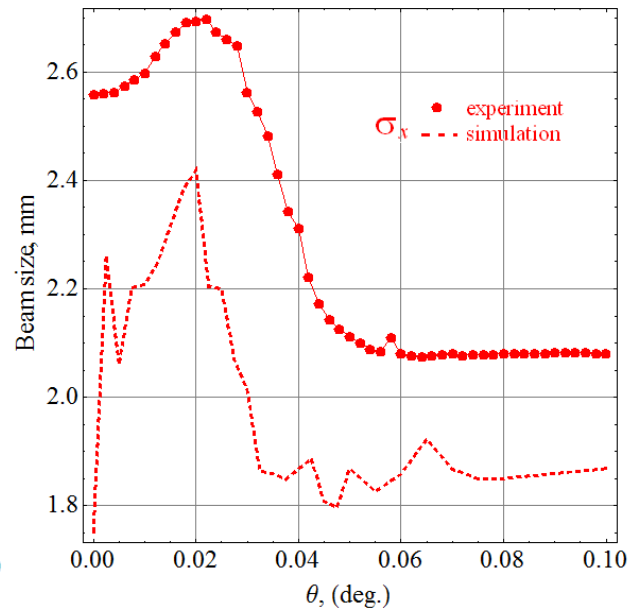
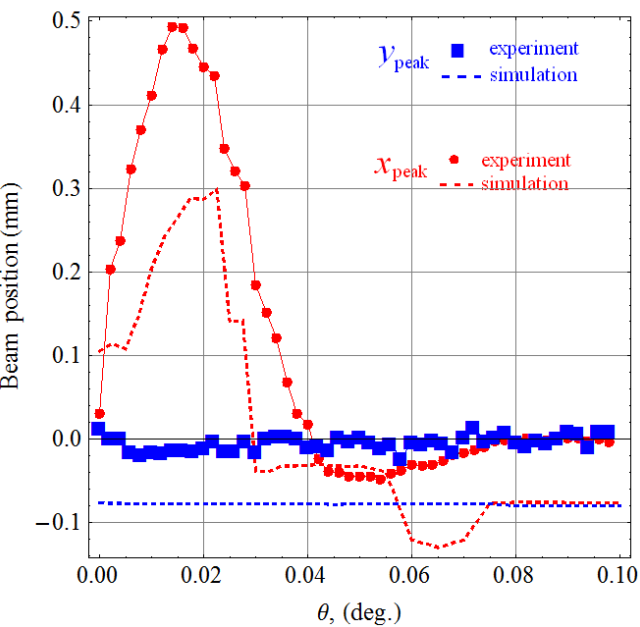
## Simulations: SAGA-LS incident beam profile



# Simulation results: beam position and beam size at (220) channeling in Si



# Simulation results: beam position and beam size at (220) channeling in Si



## Future plans (Collaboration SAGA-LS – Tomsk Polytechnic University)

- ❑ Scattering in **very** thin silicon crystal ( $L=1$  micrometer, electron energy 255 MeV)
- ❑ Scattering in the diamond crystal ( $L=50$  micrometers, electron energy 255 MeV): the experiment has been recently performed; data analysis & simulations are in progress
- ❑ Further studies of PXR & PXRC + search for DCR
- ❑ Experimental (first run recently completed) & theoretical investigations of the Cherenkov radiation from 255 MeV electrons in a 50- $\mu\text{m}$ -thick diamond crystal under random and aligned conditions

## Conclusions

- ❑ The first experiments on 255 MeV electrons axial and planar channeling and scattering in a thin aligned Si crystal have been performed at SAGA-LS injector Linac
- ❑ The simulations of trajectories at (220) planar channeling in Si, angular and spatial distributions of electrons on the screen monitor have been performed taking into account initial spatial and angular beam divergence of the electron beam, and multiple scattering
- ❑ Comparison of the experimental and theoretical results shows a quite good agreement
- ❑ One more proof of validity of the classical theory of relativistic electrons channeling





**Thank you for your attention !**

## Simulation results: beam position and beam size @ $\langle 100 \rangle$ channeling in Si

