DEFLECTION OF HIGH-ENERGY CHARGED PARTICLES BY MEANS OF A BENT CRYSTAL

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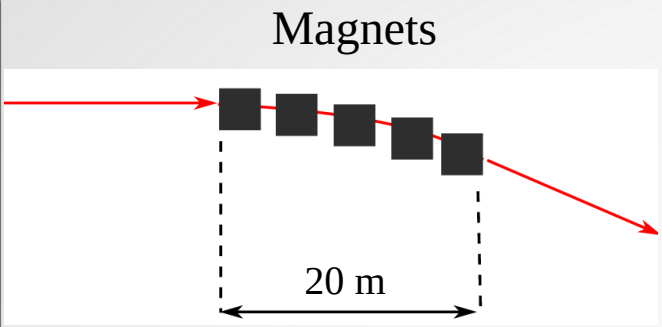
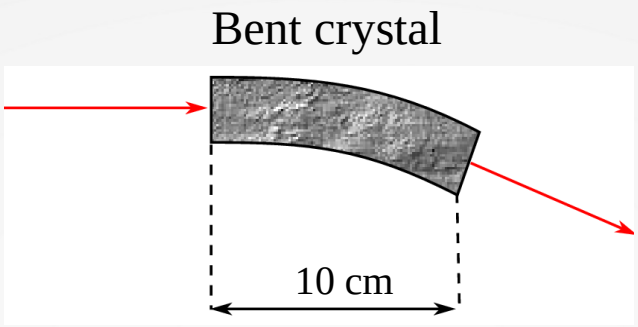
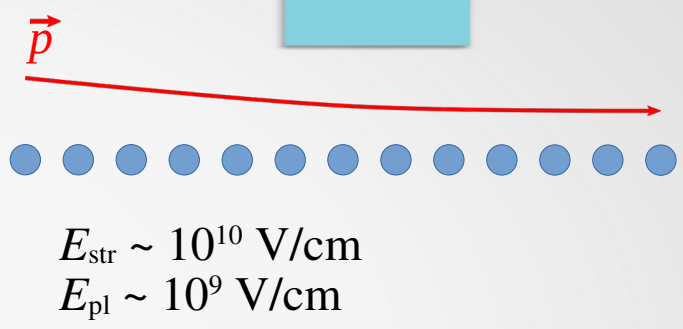
Bent crystals and magnetic deflection systems

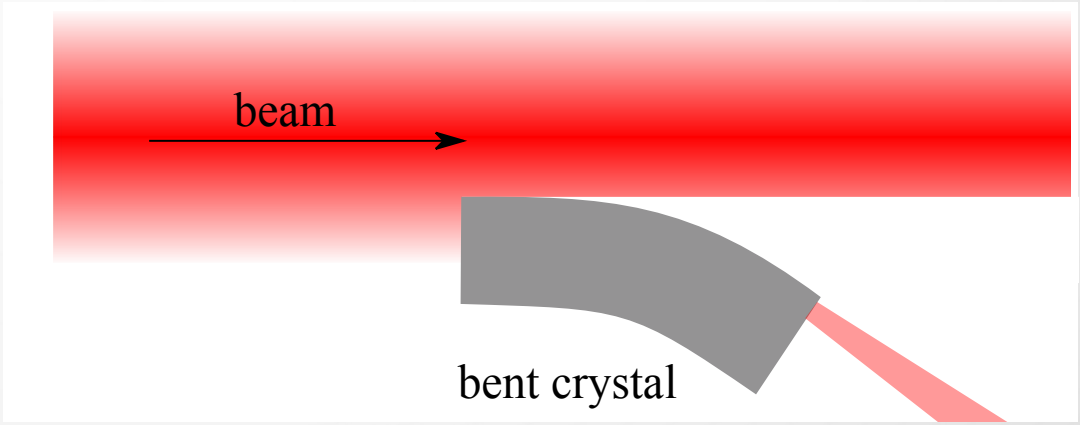






Advantages of bent crystals in comparison with magnetic deflection systems:

- Small size
- do not need electricity consumption
- do not need cooling

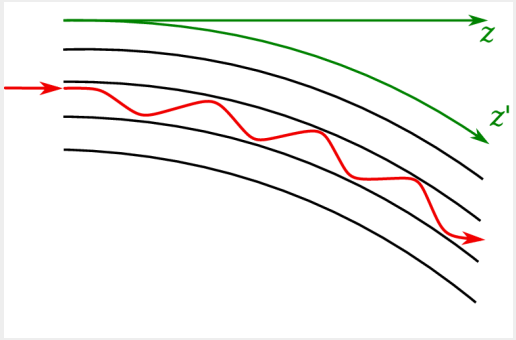


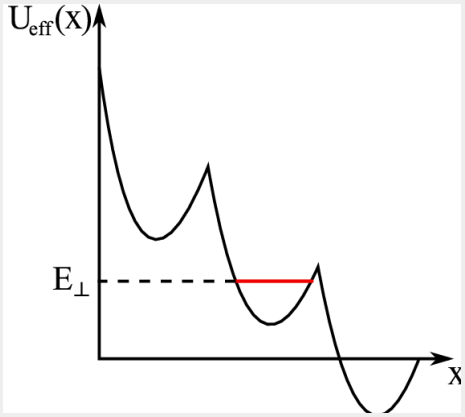
A Crystal-based Extraction for 6 GeV Electrons at DESY (G. Kube)

Sytov A., Kube, G., Bandiera, L. et al. Europ. Phys. J. C. 2022. Vol. 82. p 1-17.

Mechanisms of deflection

Planar channeling

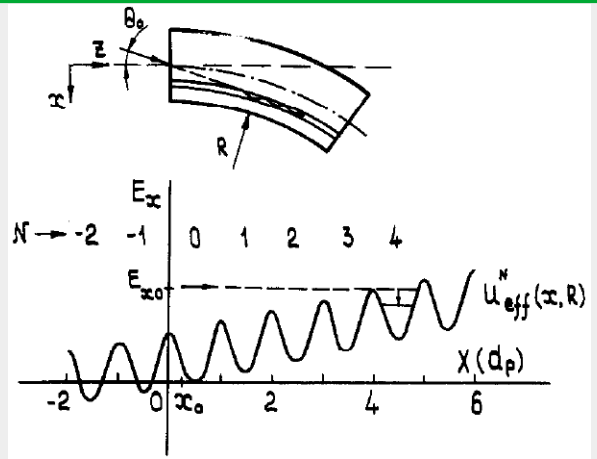


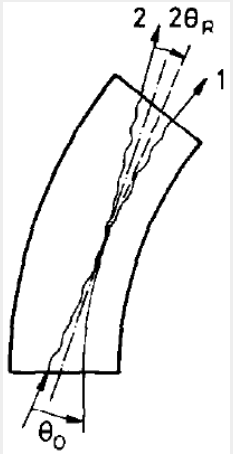


Tsyganov E. N. Fermilab TM-682, TM-684. 1976.

Volume reflection

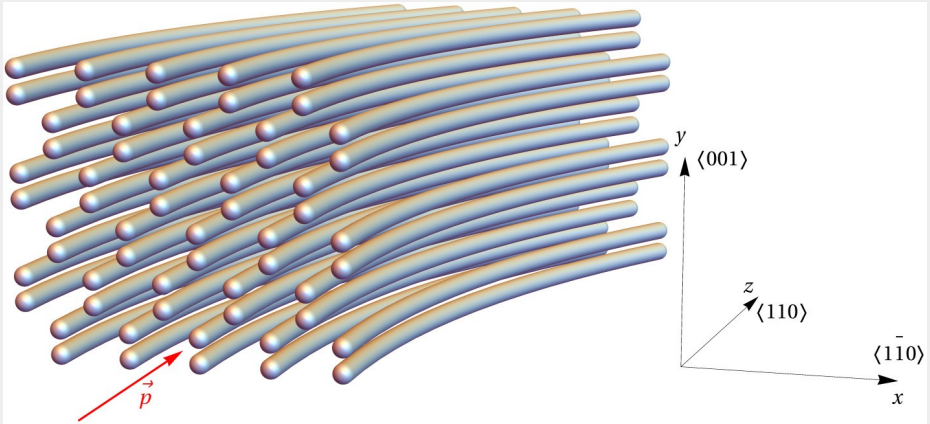
Taratin A. M., Vorobiev S. A. Phys. Lett. A. 1986. Vol. 115, No. 8. P. 398–400.





Stochastic deflection

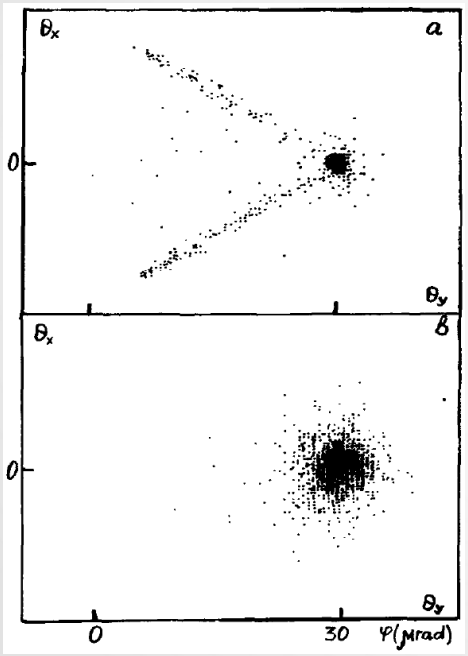
Grinenko A. A., Shul'ga N. F. J. Exp. Theor. Phys. Lett. 1991. Vol. 54. P. 524–528.



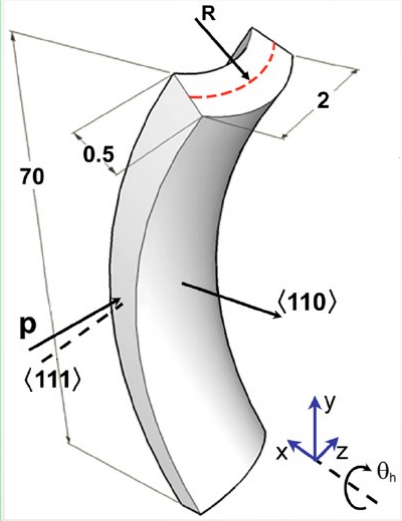
Stochastic deflection

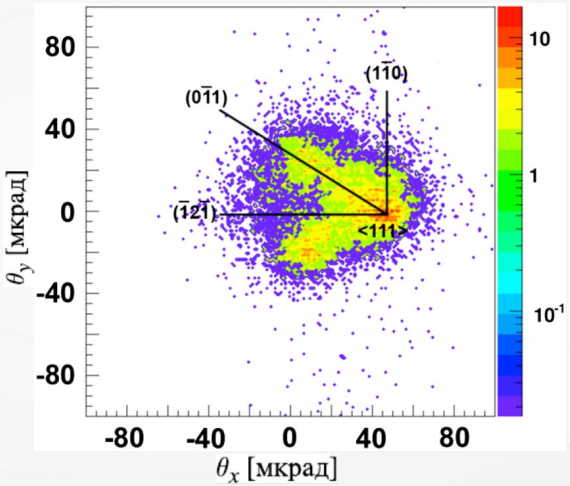
- *Grinenko A.A., Shul'ga N.F. J. Exp. Theor. Phys. Lett. 1991. Vol. 54. P. 524–528.*
- *Shul'ga N.F., Greenenko A. A. Phys. Lett. B. 1995. Vol. 353, No. 2. P. 373–377.*
- *Kyryllin I.V., Shul'ga N.F. Eur. Phys. J. C. 2019. Vol. 79. P. 1015 (1–6).*

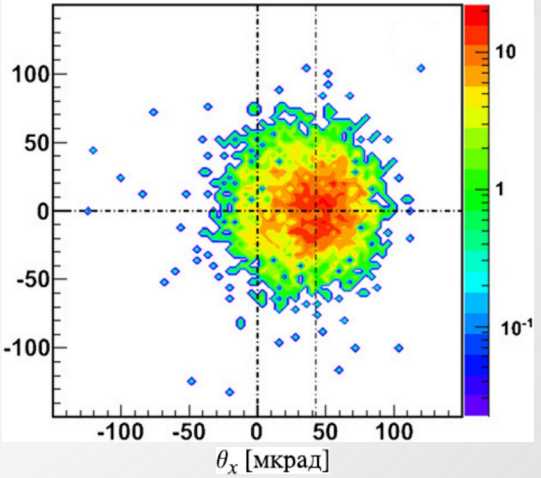
$$\langle \psi^2 \rangle = \frac{lL}{R^2} \leq \psi_c^2$$



E=10 TeV



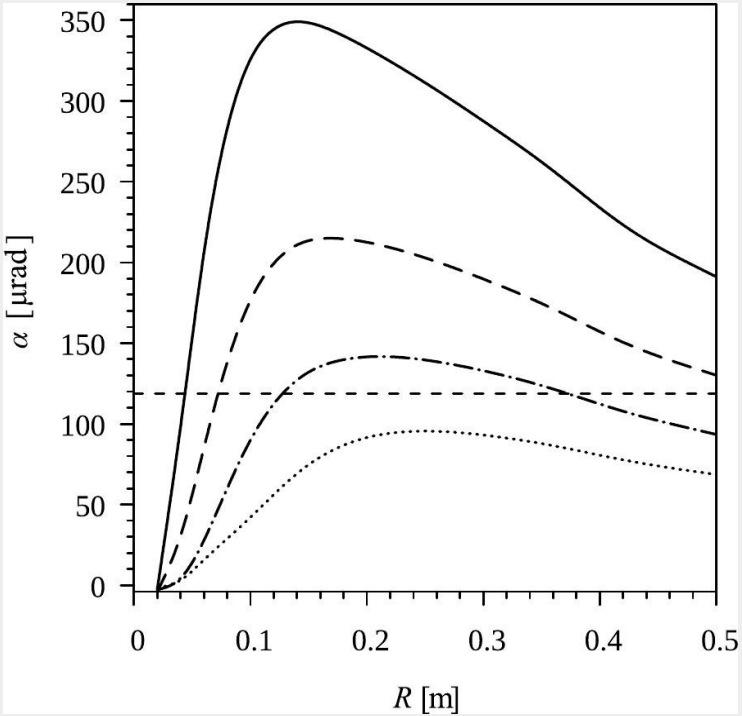




- *Scandale W., Vomiero A., Baricordi S. et al. Phys. Rev. Lett. 2008. Vol. 101, No. 16. P. 164801.*
- *Scandale W., Vomiero A., Bagli E. et al. Phys. Lett. B. 2009. Vol. 680, No. 4. P. 301–304.*
- *Bandiera L., Mazzolari A., Bagli E. et al. Eur. Phys. J. C. 2016. Vol. 76. P. 80 (1–6).*
- *Bandiera L., Kyryllin I.V., Brizzolari C. et al. Eur. Phys. J. C. 2021. Vol. 81. P. 238 (1–10).*

Dependence of the maximum deflection angle of of antiprotons with a kinetic energy of 14 GeV on the bending radius of the crystal

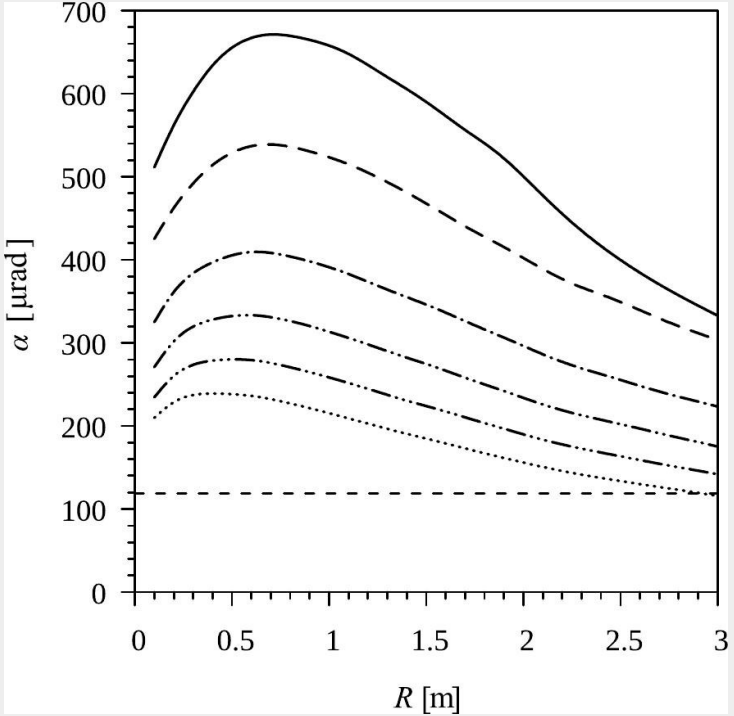
Si (110), planar channeling



$$\alpha_{\mathrm{p}} = \frac{l_{\mathrm{p}}}{R} = \frac{\theta_{\mathrm{c}}^2}{2\xi_{\mathrm{p}}^2 R \left(\mathrm{erf}^{-1}\left(\frac{f}{1-\sqrt{\frac{R_{\mathrm{c}}}{R}}} \right) \right)^2}$$

$f = 0.05$
$f = 0.10$
$f = 0.15$
$f = 0.20$

Si <110>, stochastic deflection



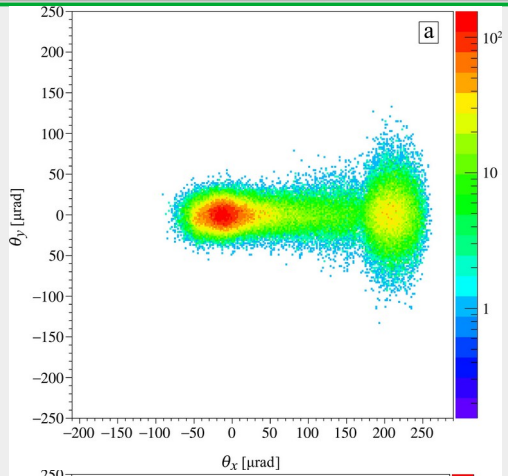
$$\alpha_{st} = \frac{L_{st}}{R} = \frac{\psi_m^2}{l/R + \xi R}$$

$f = 0.05$
$f = 0.10$
$f = 0.20$
$f = 0.30$
$f = 0.40$
$f = 0.50$

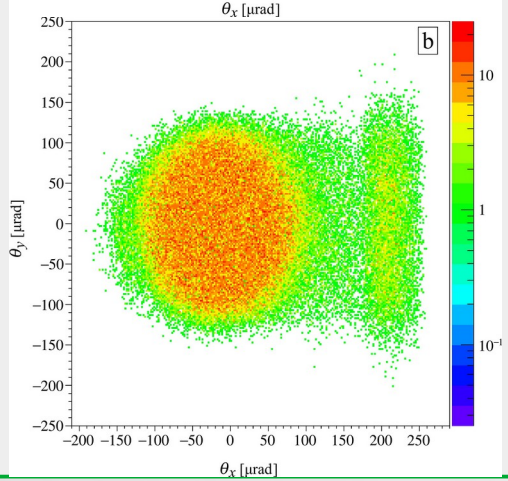
Influence of the initial angular divergence of the beam

Si (110), planar channeling, E_{kin}=14 GeV

$\Delta\psi_{in}$=0

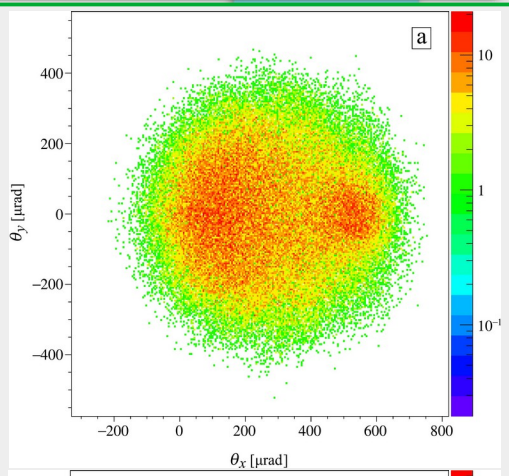


$\Delta\psi_{in}=2\psi_c$= =237.6 μrad

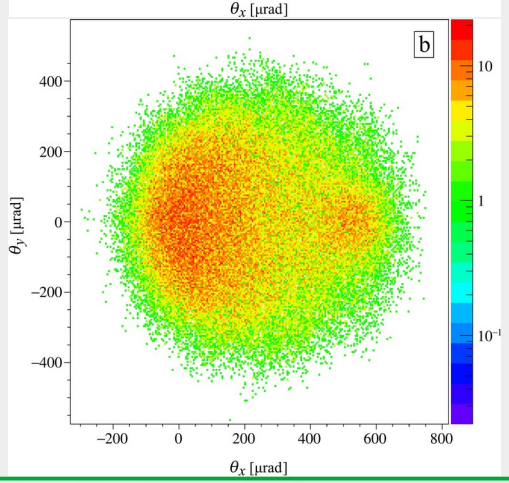


Si <110>, stochastic deflection, E_{kin}=14 GeV

$\Delta\psi_{in}$=0



$\Delta\psi_{in}=2\psi_c$= =237.6 μrad



Some of our the results in this area in recent years:

- Shul'ga N.F., Truten' V.I., Kirillin I.V. Mechanisms of high energy charged particles beams deflection by a bent crystal. *J. Phys. Conf. Ser*. 2010. Vol. 236. P. 012030 (1–5).
- Шульга Н. Ф., Трутень В.И., Кириллин И.В. Прохождение пучков быстрых заряженных частиц через изогнутый кристалл. *Вестник Харьковского университета. Серия физическая «Ядра, частицы, поля»*. 2010. Т. 887. С. 54–64.
- Shul'ga N.F., Kirillin I.V., Truten' V.I. Stochastic mechanism of a high-energy charged-particle beam deflection by a bent crystal. *Nuovo Cimento C*. 2011. Vol. 34. P. 425–429.
- Shul'ga N.F., Kirillin I.V., Truten' V.I. Dynamical chaos and stochastic mechanism of high-energy negatively charged particle deflection by bent crystals. *Phys. Lett. B*. 2011. Vol. 702. P. 100–104.
- Shul'ga N.F., Kirillin I.V., Truten' V.I. Stochastic Mechanism for Charged-Particle Deflection by Means of a Bent Crystal in the TeV Energy Range. *J. Surf. Invest.: X-Ray, Synchrotron Neutron Tech*. 2013. Vol. 7. № 2. P. 398–400.
- Chesnokov Yu.A., Kirillin I.V., Scandale W. et al. About the probability of close collisions during stochastic deflection of positively charged particles by a bent crystal. *Phys. Lett. B*. 2014. Vol. 731. P. 118–121.
- Kirillin I.V., Shul'ga N.F. Orientation dependence of the probability of close collisions during passage of high-energy negatively charged particle through a bent crystal. *Nucl. Instr. Meth. Phys. Res. B*. 2015. Vol. 355. P. 49–52.
- Bandiera L., Mazzolari A., Bagli E. et al. (Kirillin I.V., Shul'ga N.F.) Relaxation of axially confined 400 GeV/c protons to planar channeling in a bent crystal. *Eur. Phys. J. C*. 2016. Vol. 76. P. 80 (1–6).
- Kirillin I.V., Shul'ga N.F., Bandiera L. et al. Influence of incoherent scattering on stochastic deflection of high-energy negative particle beams in bent crystals. *Eur. Phys. J. C*. 2017. Vol. 77. P. 117 (1–7).
- Kirillin I.V., Shul'ga N.F. Dependence of the probability of close collisions of high-energy charged particles in a bent crystal on the orientation of the crystal. *Nucl. Instr. Meth. Phys. Res. B*. 2017. Vol. 402. P. 40–43.
- Bandiera L., Kirillin I.V., Bagli E. et al. (N.F. Shul'ga) Splitting of a high-energy positively-charged particle beam with a bent crystal. *Nucl. Instr. Meth. Phys. Res. B*. 2017. Vol. 402. P. 296–299.
- Kirillin I.V. On the dependence of the efficiency of stochastic mechanism of charged particle beam deflection in a bent crystal on the particle energy. *Probl. Atom. Sci. Tech*. 2017. Vol. 109. № 3. P. 67–71.
- Kirillin I.V. Optimal radius of crystal curvature for planar channeling of high-energy negatively charged particles in a bent crystal. *Phys. Rev. Accel. Beams*. 2017. Vol. 20. P. 104401 (1–5).
- Kyryllin I.V., Shul'ga N.F. Energy dependence of the efficiency of high-energy negatively charged particle beam deflection by planar channeling in a bent crystal. *Eur. Phys. J. C*. 2019. Vol. 79. P. 1015 (1–6).
- Bandiera L., Kyryllin I.V., Brizzolari C. et al. (N.F. Shul'ga) Investigation on steering of ultrarelativistic $e^{\pm}$ beam through an axially oriented bent crystal. *Eur. Phys. J. C*. 2021. Vol. 81. P. 238 (1–10).

Thank you for attention!

And many thanks for the opportunity to use

computing resources of DESY to run the simulations!