Channeling Experiments with Electrons at the Mainz Microtron MAMI

1. Motivation
2. Channeling Experiments with Positrons @BTF Frascati
3. Channeling Experiments with Electrons @MAMI Mainz
4. Measurements of the Dechanneling Length
5. A Planar Channeling Experiment with Electrons using a Periodic Graded Composition Strained Layer SiGe Target
6. Conclusions

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Undulator Radiation at Positron/Electron Channeling in a Single Crystal

A. Solov’yov, A. Korol, W. Greiner et al.
Positron Channeling in Si-Undulator Crystal

\[ x = A \cdot \cos \left( \frac{2\pi}{\lambda_u} z \right) \quad A = 9 \text{ Å}, \quad \lambda_u = 50 \text{ µm}, \quad N_u = 4 \]

Beam Energy \( E = 600 \text{ MeV}, \quad \gamma = 1175.2 \)

\[ K = \gamma \cdot A \cdot \frac{2\pi}{\lambda_u} = 0.133 \]

Photon energy

\[ \hbar \omega = k \frac{4\pi \cdot \gamma^2 \hbar c}{\lambda_u (1 + K^2 / 2 + \gamma^2 (\theta_x^2 + \theta_y^2))} = 67.9 \text{ keV} \]

at \( \theta_x = \theta_y = 0 \), and first order \( k = 1 \)
Channeling Experiments with Positrons @BTF Frascati
Beam Test Facility (BTF)

(See Poster Lina Quintieri)

Emittance: $\varepsilon_x = \varepsilon_y = 10 \text{ mm mrad}$

Divergence: $\sigma'_x = \sigma'_y = 2 \text{ mrad}$ ($\psi_C = 0.27 \text{ mrad}$)

Beam Spot Size: $\sigma_x = \sigma_y = 5 \text{ mm (rms)}$

Energy: $25 - 600 \text{ MeV}$

Particles: $1 - 10^{10}$ per pulse

Repetition rate: $50 \text{ Hz}$

800 MeV Electrons, Positrons from Linac

Conversion Target

Slit for Energy Definition

Experimental Hall

800 MeV Electrons, Positrons from Linac

Conversion Target

Slit for Energy Definition

Experimental Hall
Experimental Setup @ BTF

Plastic Scintillator

Pb beam dump

250 mm

350 mm

2" Nal Detector

Pb shield

250 mm

250 mm

Goniometer with Si-Crystal

Mylar Window d = 0.04 mm

Be Window d = 0.5 mm

d = 2600 mm

e^+
Experimental Result

![Graph showing experimental result](image)

- **NaI Signal [a.u.](normalized over beam intensity)** vs. **\( \varphi \) [mrad]**

The graph illustrates the variation of the NaI signal (normalized over beam intensity) with respect to the angle \( \varphi \) in milliradians (mrad). The data points indicate a relatively flat trend, suggesting minimal change in the signal over the range of \( \varphi \) from 0 to 160 mrad.
Improvement of the Beam line

Target Chamber

Addition 45° Magnet

Existing 45° Magnet

Detectors

To Beam Dump

BTF Hall

1m
Experiments with Electrons

Dechanneling Length
Parameter:
Energy: 180 MeV - 1507 MeV
Emittance $\varepsilon_x = 9 \text{ nm rad}$, $\varepsilon_y = 0.5 \text{ nm rad}$
Energy Stability: $7 \cdot 10^{-5}$
100$\mu$A $\text{cw} \text{ e}^-$ beam

Phase Contrast (Beamspot $\sim 1\mu$m)
X-ray Interferometry (Magnetic circular Dichroism)
PXR, TR, Channeling

Experimental Setup (855 MeV e⁻)

Top View

Si Target

BM1

ZnS Screen

Camera

Beam Dump

Ionization Chamber

Nal Detector
(10" Ø × 10" length)

Rad. Length
$X_0=10$

Pb 100 mm
Ø 20 mm

7.633 m

44°
Target Setup and Definition of Angles

Top View

- Polar Angle ($\theta$)
- Azimuth ($\phi$)
- Tilt Angle ($\alpha$)

Diagram:
- $e^-$
- $y$, $y''$
- $x'$, $x$
- $\theta$, $\phi$, $\alpha$
Video of the Beam Spot at the Dump Screen

uvso81024-005.AVI
NaI Raw Spectra

174µm Si Crystal

Events [1/s] vs $\hbar \omega$ [keV]

Events [1/s] vs $\hbar \omega$ [MeV]

(111)

(110)

(100)

Off Channeling
Energy - angle dependence of the radiation

Channeling and Quasichanneling

Events

Angle $\phi$ [mrad]

Energy $E$ [MeV]

Channeling and Quasichanneling

Events

Angle $\phi$ [mrad]

Energy $E$ [MeV]

6 MeV

0.6 MeV

(011)

(013)

(001)

(010)
Energy - angle dependence of the radiation

- Coherent Bremsstrahlung
- High energy Bremsstrahlung
Dechanneling length @ $E_e = 855$ MeV

Photon energy: $> 100$ MeV (Bremsstrahlung)

\[ f(x) = f_0 (1 - e^{-x/d}) \]

\[ d = (19.6 \pm 1) \mu m \]
Dechanneling length @ $E_e = 195$ MeV

Photon energy: $> 12$ MeV (Bremsstrahlung)

$$ f(x) = f_0 (1 - e^{-x/d}) $$

$$ d = (18.5 \pm 3) \mu m $$
Dechanneling length @ $E_e = 855$ MeV

Photon energy: < 5 MeV (Channeling Radiation)

No saturation
Can be explained with channeling / rechanneling processes

Fokker-Planck Equation $\rightarrow$

$d = 18 \mu m$

H. Backe et al.
NIM B 266(2008) 3835
Dechanneling Length versus Electron Energy

21.3 μm/GeV
Channeling with periodically bent crystals
Experimental Setup @1.5GeV

Top View

- Ionization Chamber
- Beam Dump
- Goniometer
- 300 Plastic Scintillators
- Tagger Magnet
- Aperture \( \Phi 3\text{mm} \)
- Nal Detector (10"\( \Phi \) x 10" length)
- Pb 100 mm \( \Phi 45\text{mm} \)
- Si-Crystals
- Undulating crystal
- Flat crystal
- 7.633 m
Scan around the vertical axis $\Phi$
Bent crystal

Aarhus-Kristall
28-08-08
wipp=-1.8°
Psi=178°
Phi:-10°->10°
0.1°/s

Signal Ionisation Chamber (log) [V]

(111)
(100)
(110)

no Channeling

(110)
Scan around the vertical axis $\Phi$

Flat crystal

Signal Ionisation Chamber (log) [V]

$\phi$ [Degree]

Flat Crystal
200 µm
28-08-21
wipp=-1.8°
Psi=178°
Phi:-10°->10°
0.1°/s

(100)
(111)
(110)

no Channeling
Raw Data

Events [1/s]

Energy [keV]

- Red: Aarhus 110
- Pink: Aarhus No-Channeling
- Blue: 200mu 110
- Purple: 200mu No-Channeling

Directory: C:\x1messpc2\Strahlzeitdaten\X-Strahlzeiten\CU-beiA2-26-08-08\uswertung\File: Online-28-08-08-new.0q
Worksheet: Dat1_B, Grafikfenster: RohspektrenP

Rohspektren ohne Skalierung nur Zeitnormiert
Raw Data

![Graph](image-url)

**Events [1/s]**

**Energy [keV]**

- Red: Aarhus 110
- Pink: Aarhus No-Channeling
- Blue: 200µ 110
- Purple: 200µ No-Channeling

Data sourced from:
- Directory: C:\x1messpc2\Strahlzeitdaten\X-Strahlzeiten\CU-heA-26-08-08\uswertung\Online-28-08-08-new.opj
- Worksheet: Dat1_B
- Grafikfenster: Graph3

Rohspektren ohne Skalierung nur Zeitnormiert
Channeling Spectra (110) Plane

Events [1/s]
Energy [keV]

Diff-Aa-110-U
Diff-200mu-110-U

Differenzen Peak - Aulßerhalb ohne Skalierung
Difference Spectra Bent-Flat

Events

Energy [keV]

0,0
0,5
1,0

0 5000 10000 15000 20000

0,0
0,5
1,0

Diff:Aa-200mu:<110>
Diff:Aa-200mu:<U>

200 µm Kristall * 0.73

Events

Energy [keV]
Difference Spectra Bent-Flat

Events

Energy [keV]

0 500 1000 1500 2000

0,0

0,5

1,0

Red: Difference <110> Aarhus - 200µm
Blue: Difference außerhalb Aarhus - 200µm

200 µm Kristall * 0.73
Conclusions

• For Positron channeling a suitable machine is missing (Upgrading of BTF)

• Dechanneling length of Electrons have been measured 21.3 µm/GeV

• With a 4 period Crystal Undulator an enhancement of radiation has been observed