Techno CLS,

Work Package 3, Experimental issues, Part 1

Experiments @ MAMI

Objectives

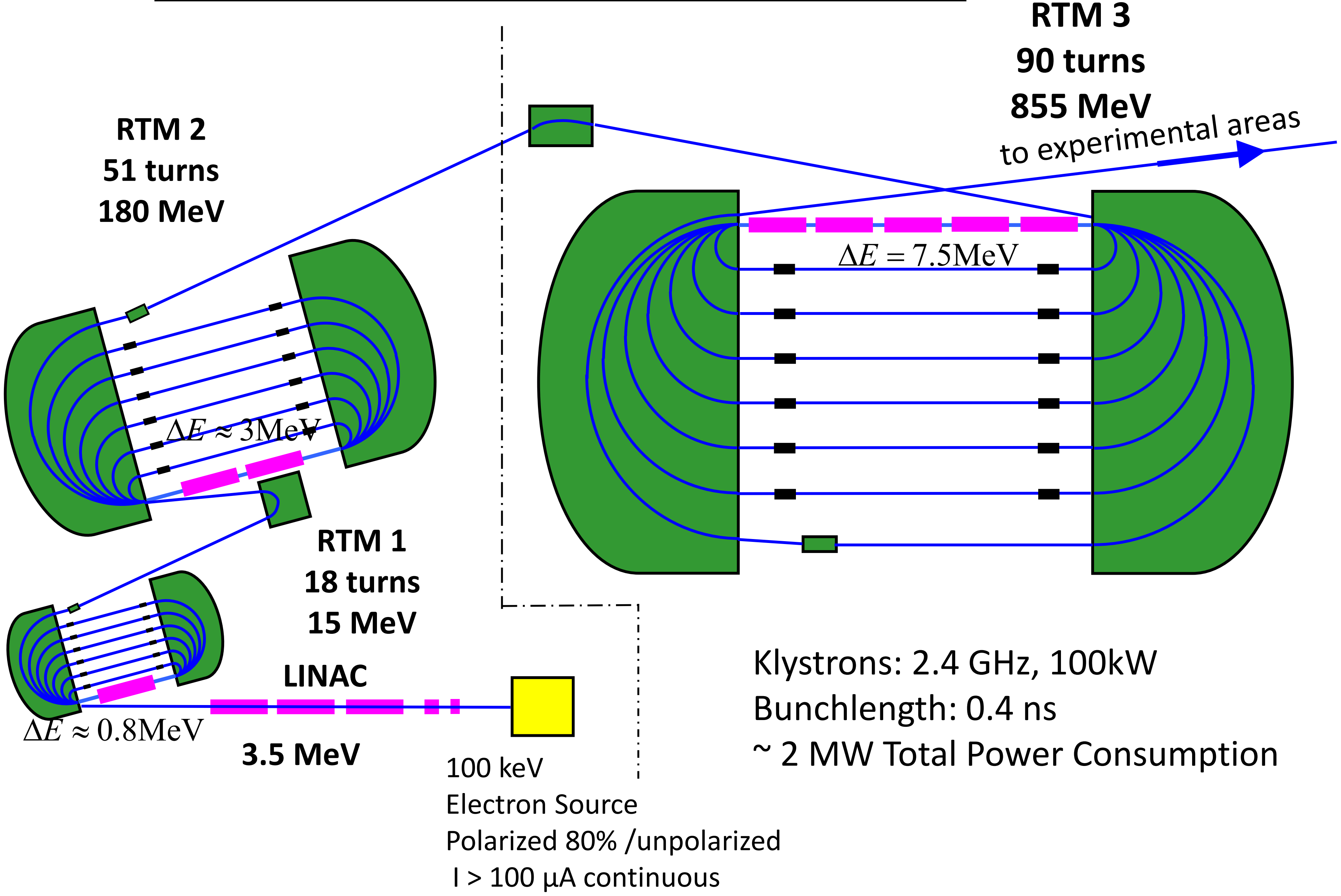
- ***O3.5*** *Channeling experiments with electrons and (positrons) in LC, BC and PBC crystals.*

- ***O3.4*** *Construction of a beam transport system for monochromatic low divergence 530 MeV positrons.*

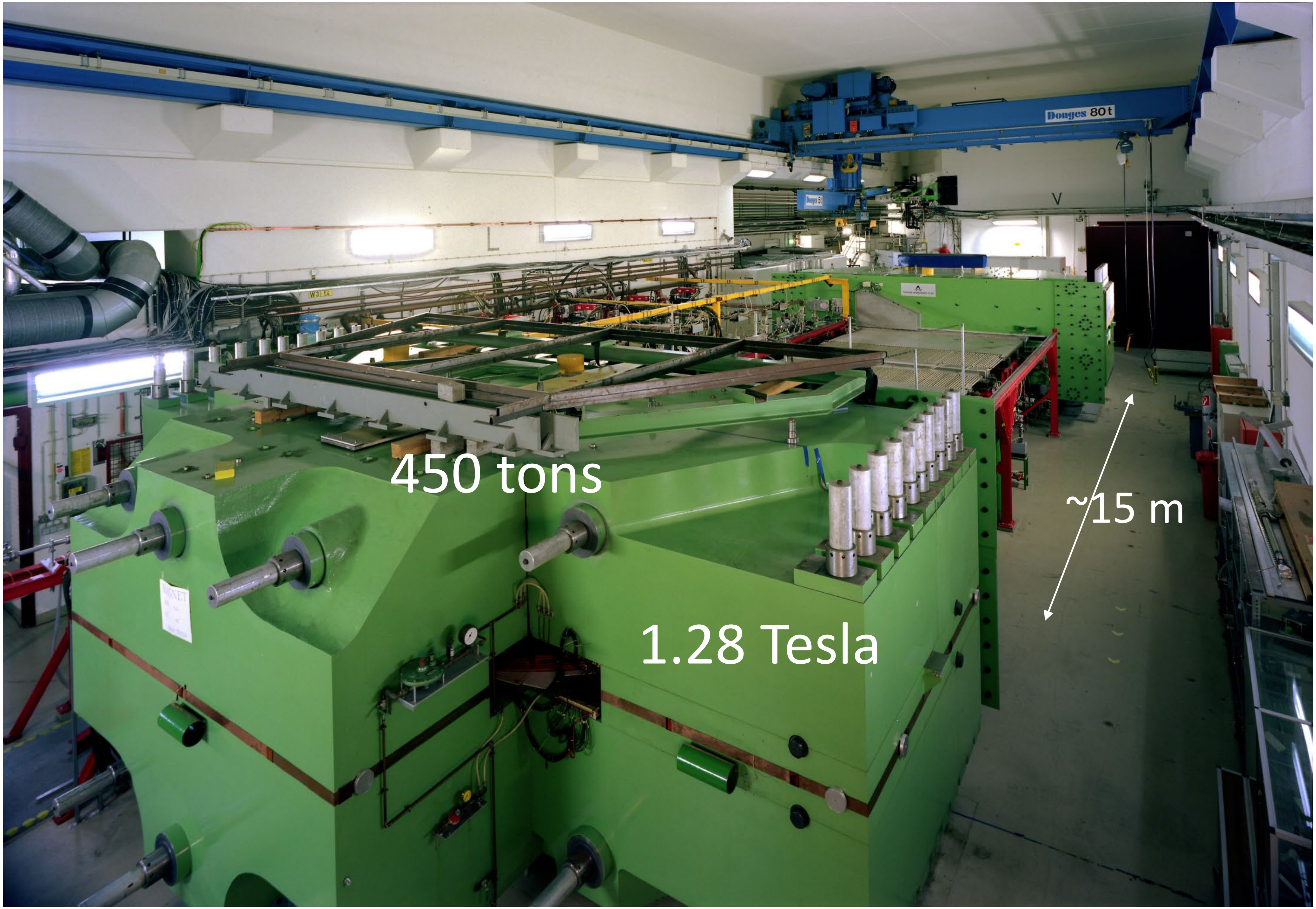
Experimental issues, Part 2 -> Talk Vincenzo Guidi WP3

W. Lauth, University of Mainz, Germany, Techno CLS Meeting, Online, June 2024,

Mainzer Mikrotron MAMI B



Klystrons: 2.4 GHz, 100kW
Bunchlength: 0.4 ns
~ 2 MW Total Power Consumption


450 tons
1.28 Tesla
~15 m
Donges 80 t

Ground plan of MAMI

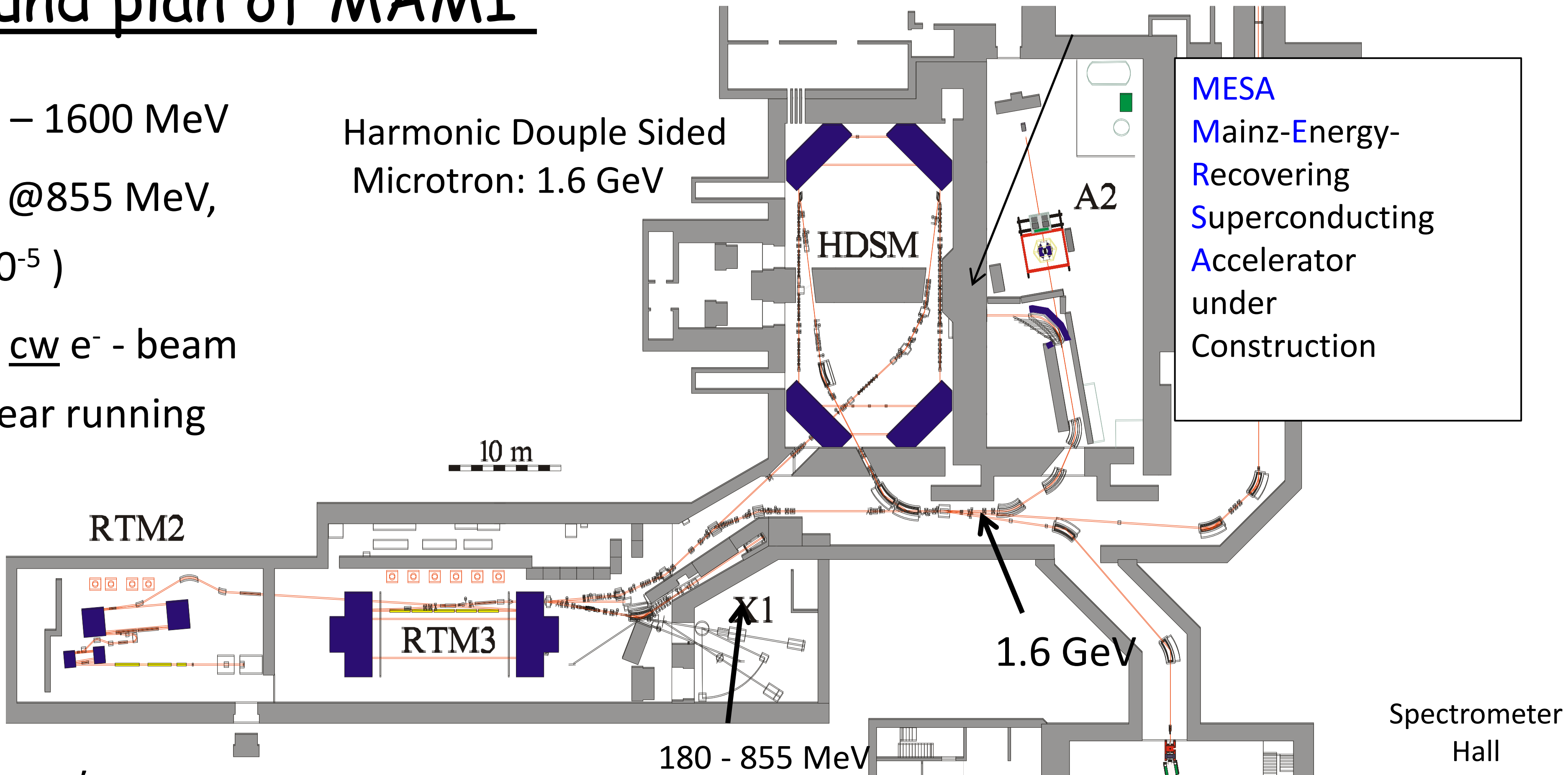
E= 180 MeV – 1600 MeV

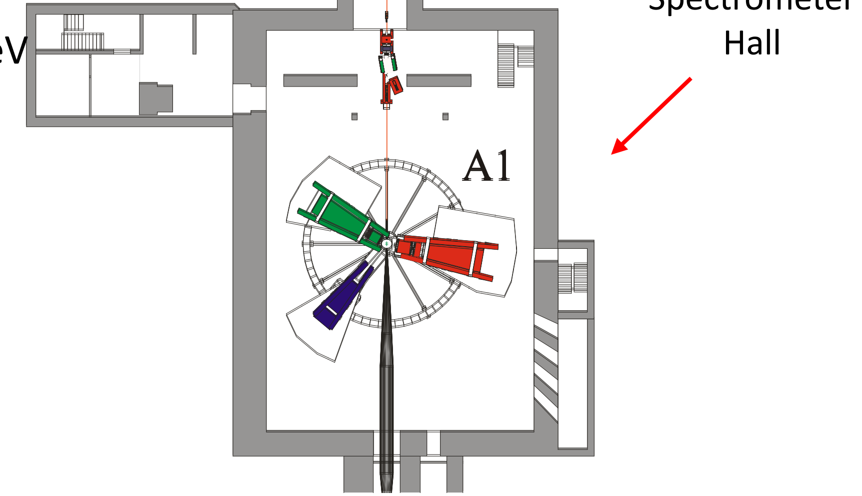
ΔE = 13 keV @855 MeV,

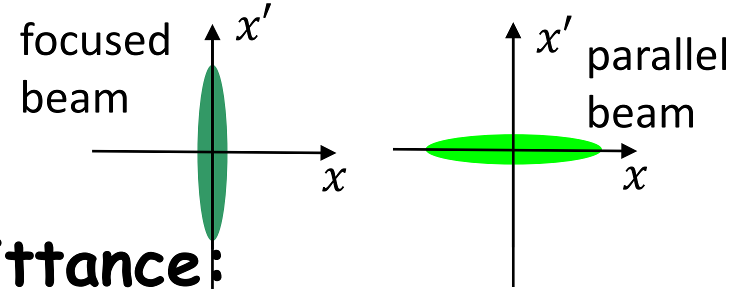
$\Delta E/E = (2 \cdot 10^{-5})$

max. 100µA cw e^- - beam

~ 7000 h / year running







Emittance:

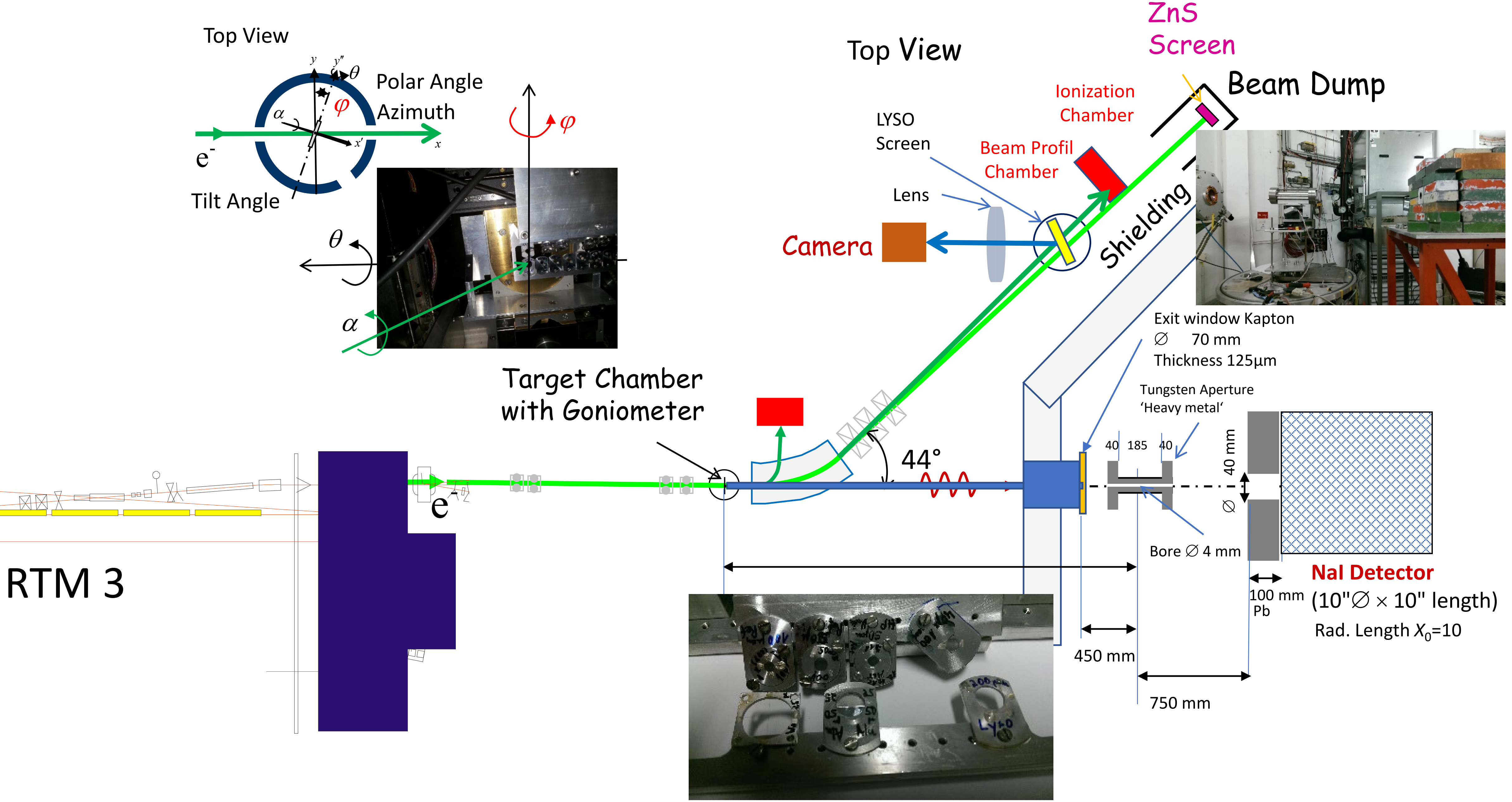
Vertical : e_y= 1 µm mrad = 1 mm µrad

Horizontal: e_x=8 nm rad

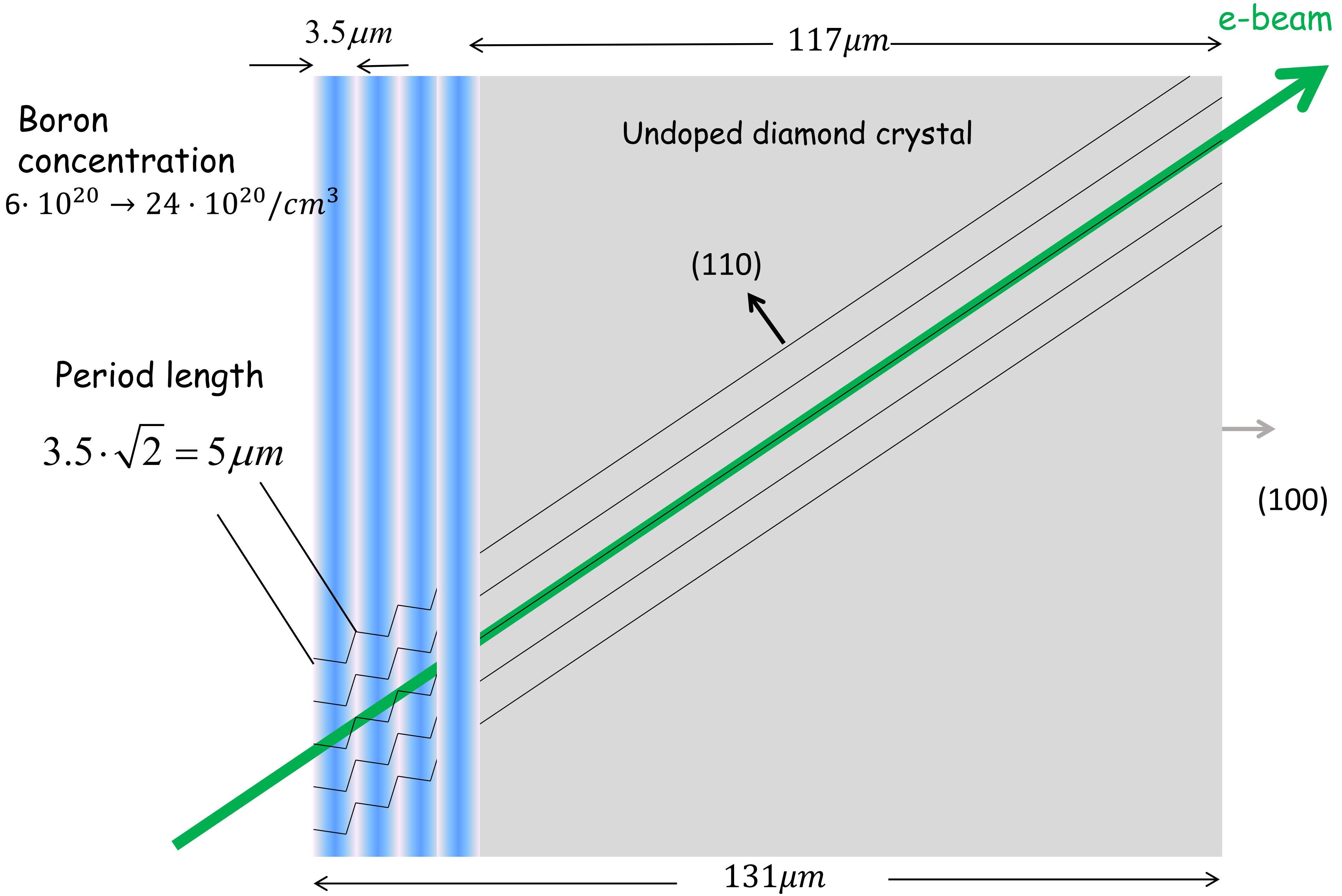
Task T3.5

Measurement of radiation produced with channelled electrons (and positrons).

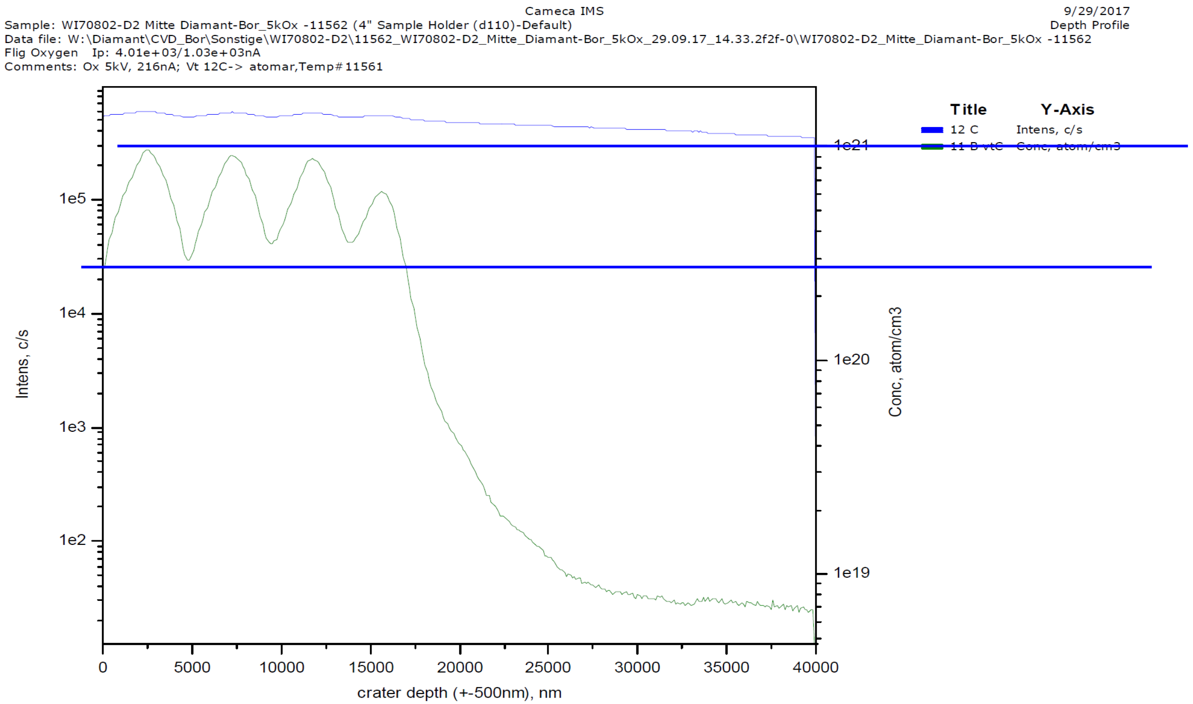
Experimental Setup (855) MeV e^-



'New' 4 Period Diamond Undulator

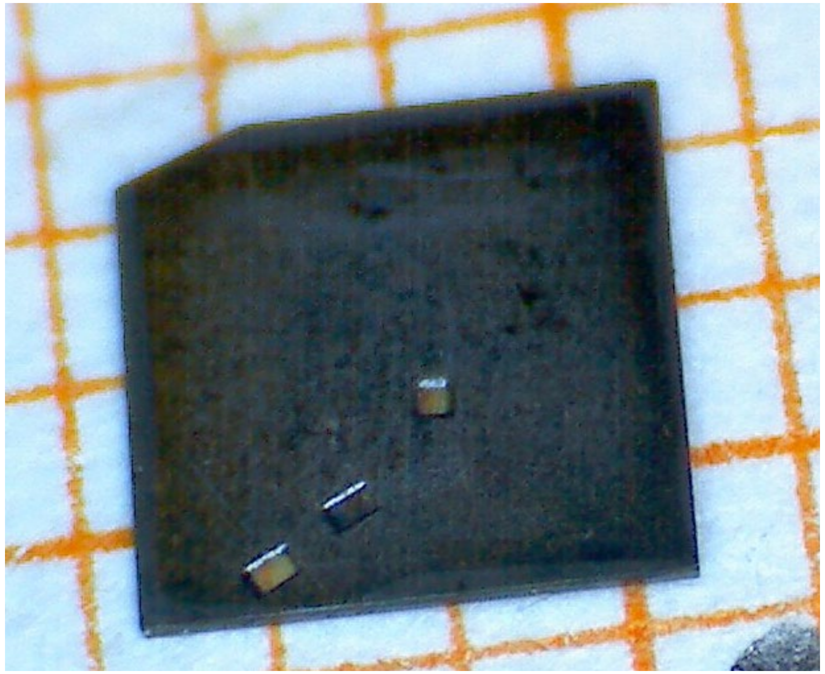


SIMS Profile - Bor concentration



$9 \cdot 10^{20}/cm^3 = 0.5\%$

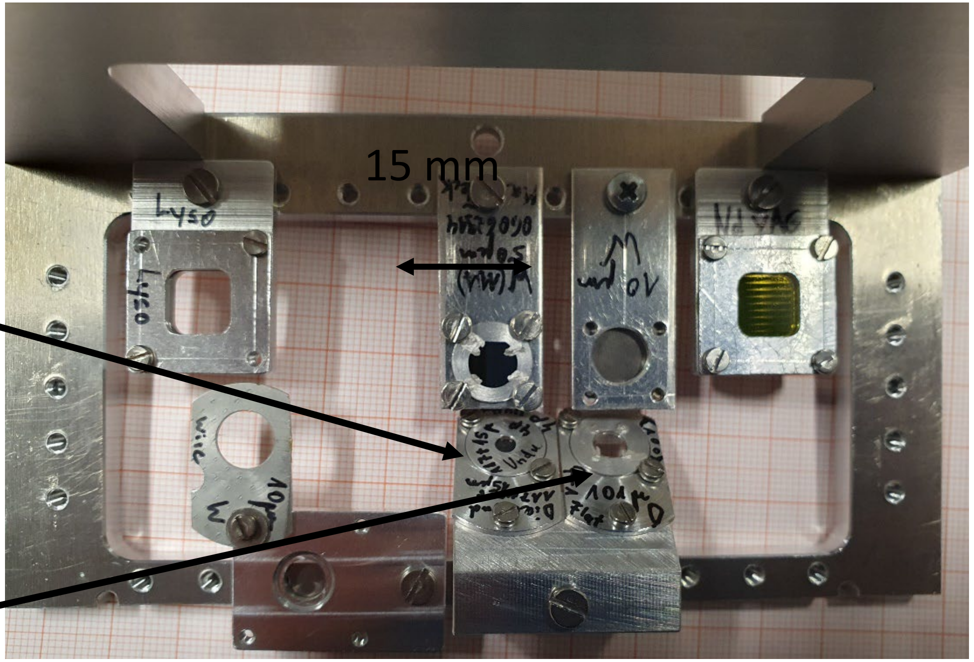
$3 \cdot 10^{20} = 0.17\%$

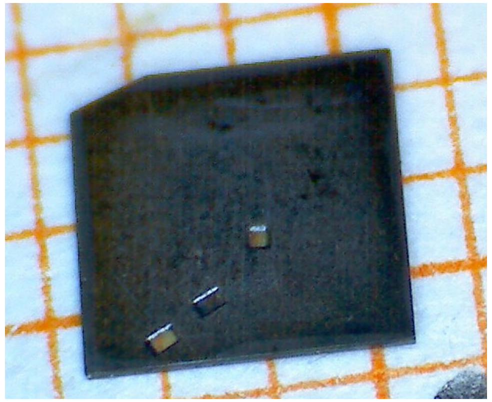


Talk of Rebecca Dowek

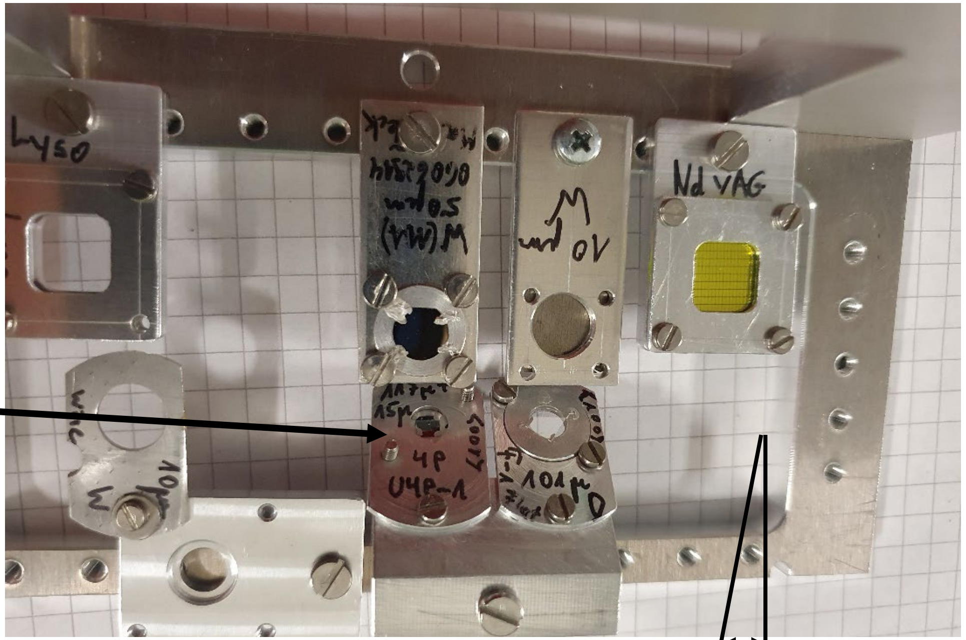
4 period
Diamond crystal

101 µm flat
Diamond crystal
reference



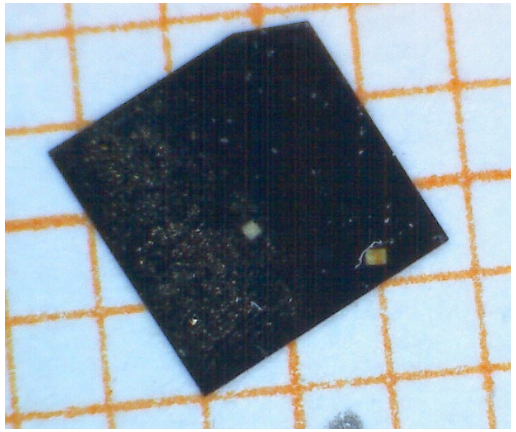


SIMS
holes

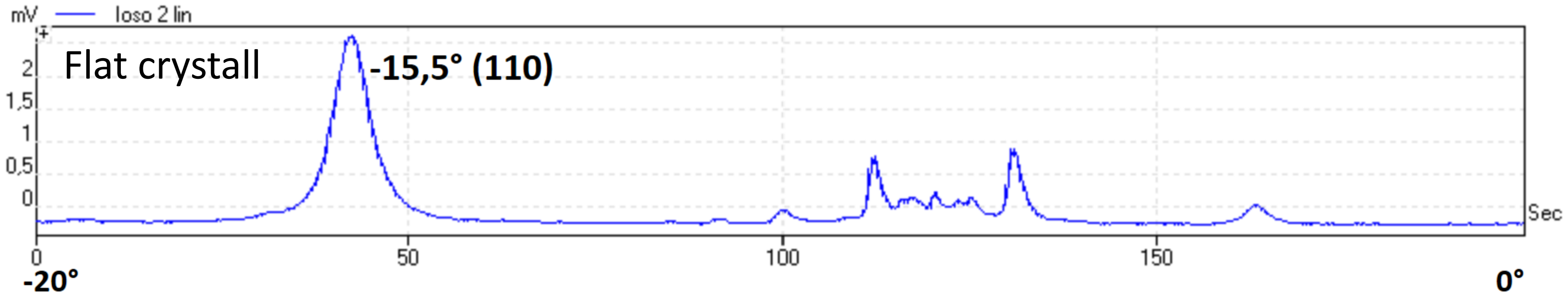


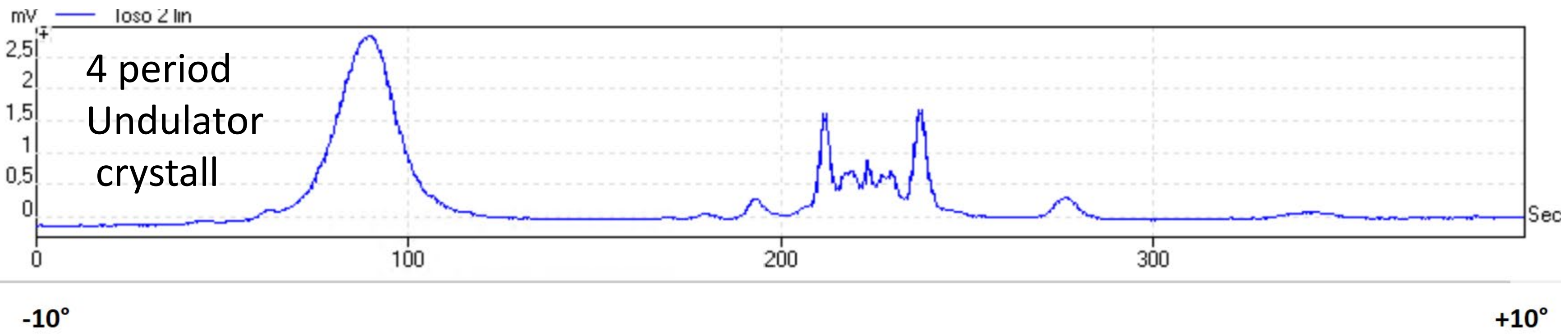
4 period
Diamond crystal
Flip configuration

45°



Scans with Ionisation chamber



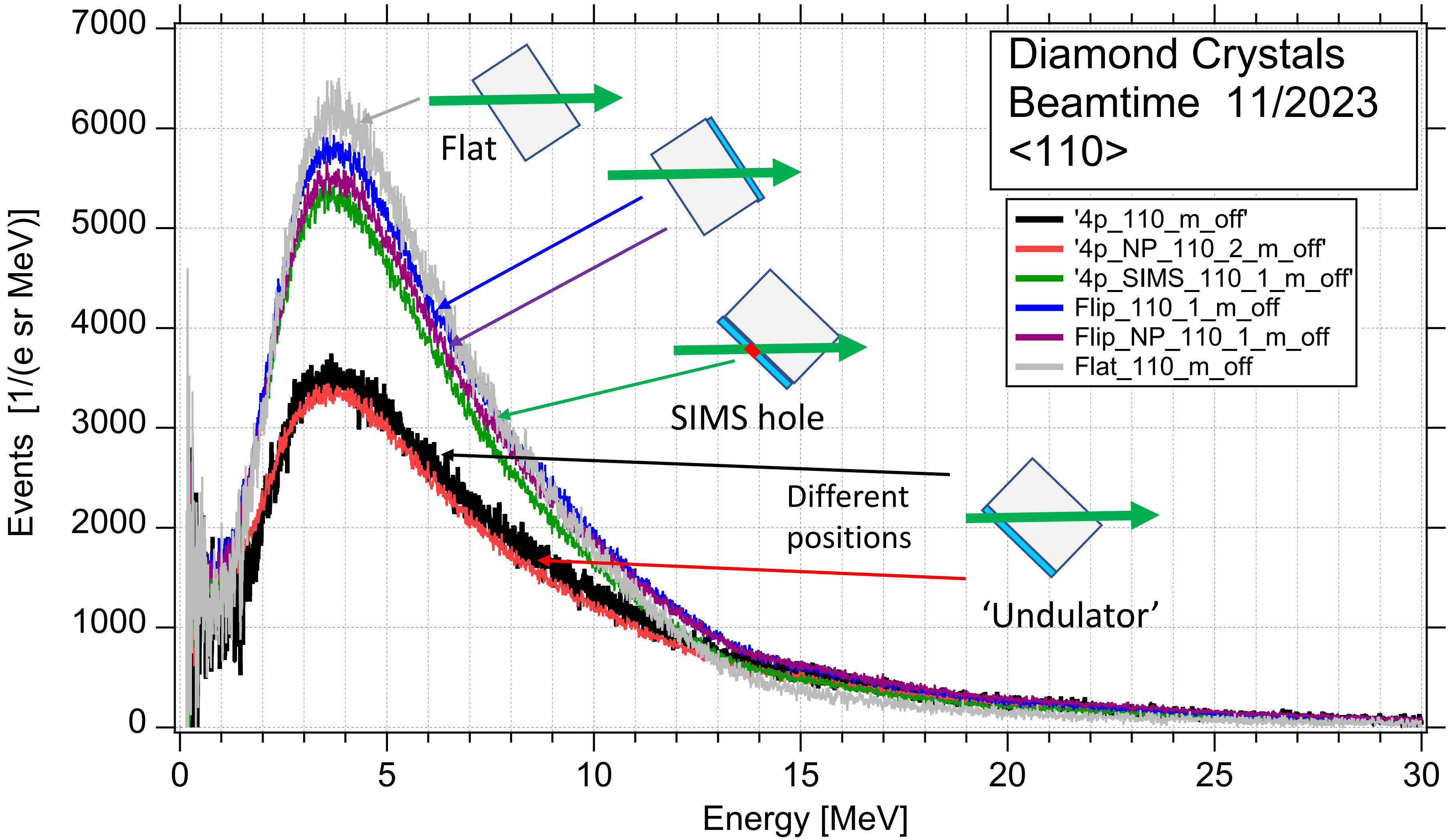


4 Period Diamond crystal, 855 MeV

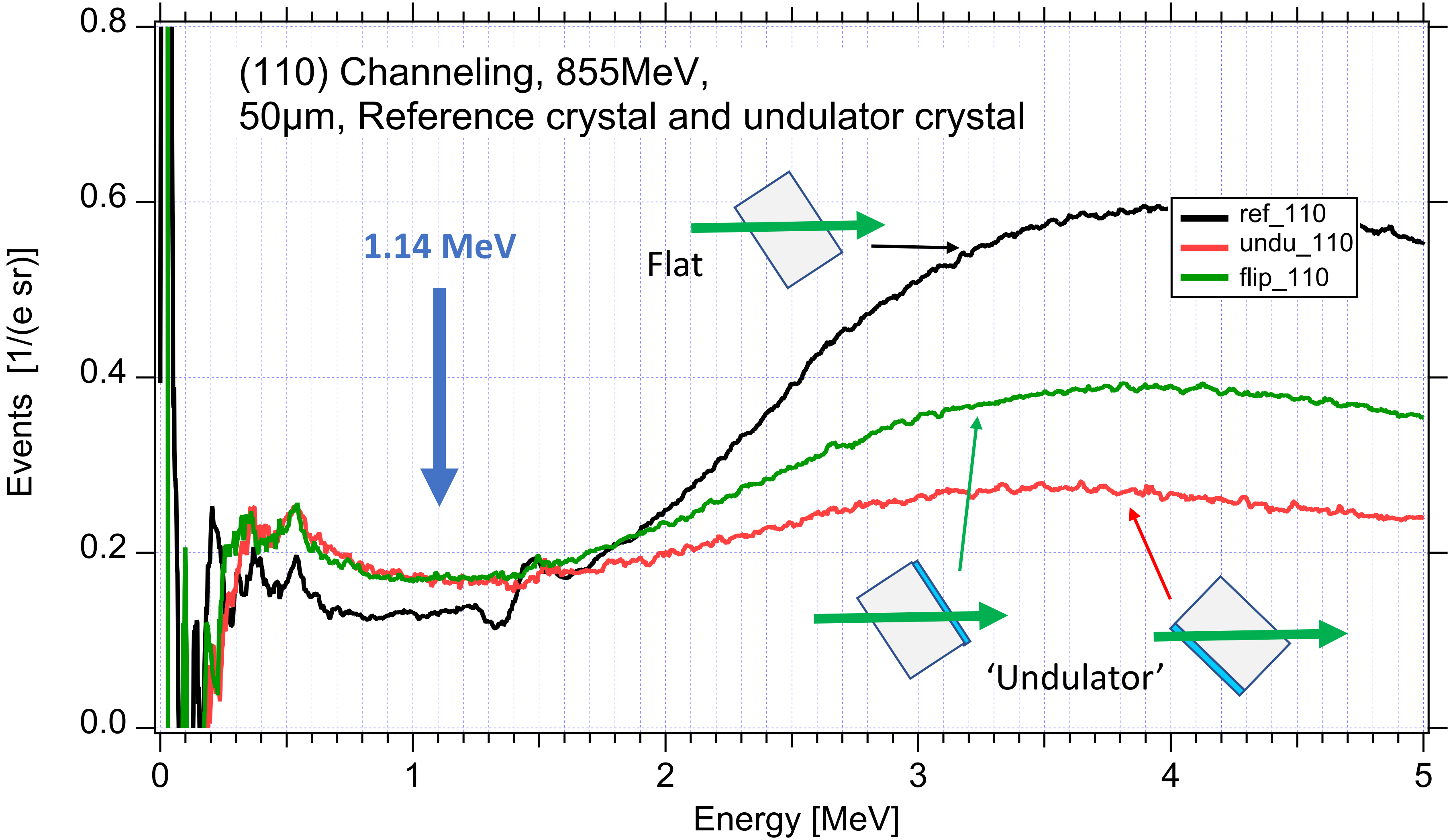
$$\hbar\omega = k\frac{4\pi\cdot\gamma^2\hbar c}{\lambda_U(1+K^2/2+\gamma^2(\theta_x^2+\theta_y^2))} = 1.136\ MeV$$

at $\theta_x = \theta_y = 0$, and first order $k = 1$

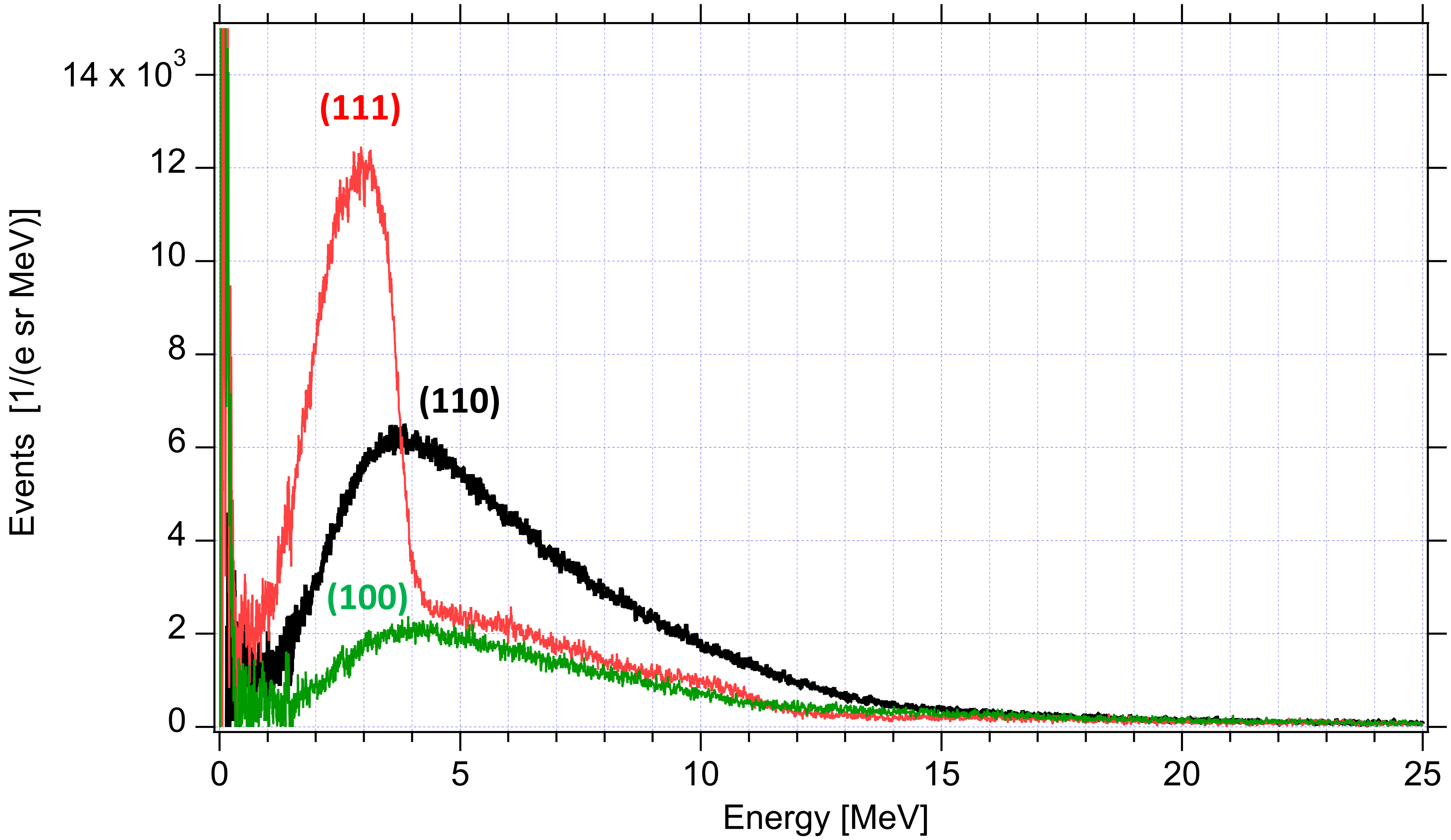
Comparison 'Undulator' – Reference crystal
(110) plane (Undulator plane)
Off axis radiation subtracted



Comparison 'Undulator' – Reference crystal
(110) plane (Undulator plane)



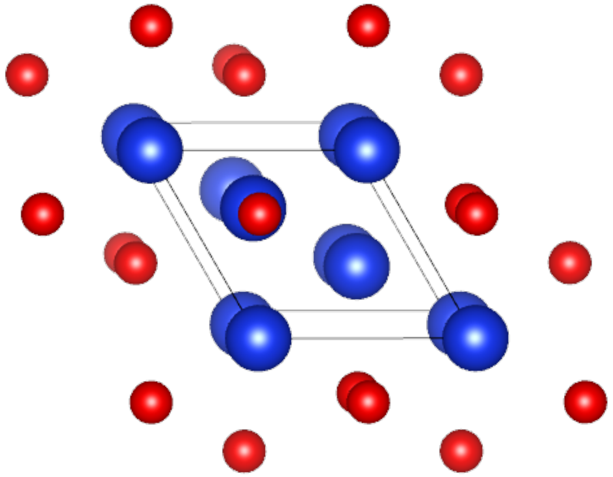
Channeling radiation of a flat diamond crystal



Channelling Radiation in Silicon Carbide

Exploration of a **new material** beside Silicon and Germanium

Low Z- atoms

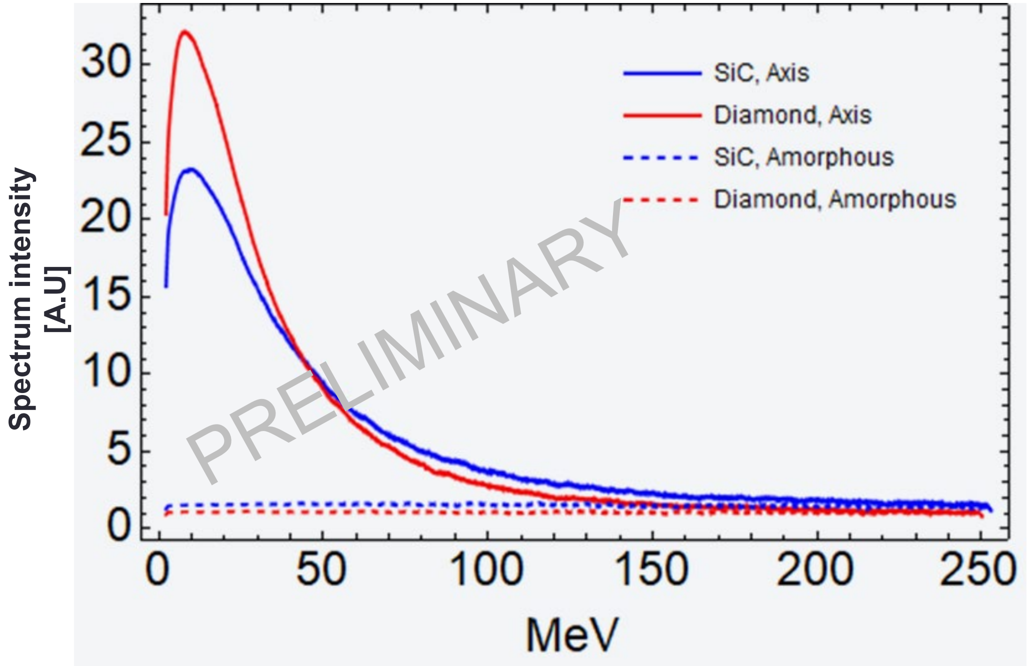


Silicon Carbide 6H
<0001> axis

LINEAR CRYSTAL
0.33 mm thickness, 4x7 mm^2 surface
channelling Axis: <0001>

lattice structure: Hexagonal (Space group #186)

e- @855 MeV



Tightly packed planes perpendicular to <0001>, featuring properties in between Si and C, being cheaper than Diamond.

SiC 6H crystal: 0.33 mm thick axis <0001>

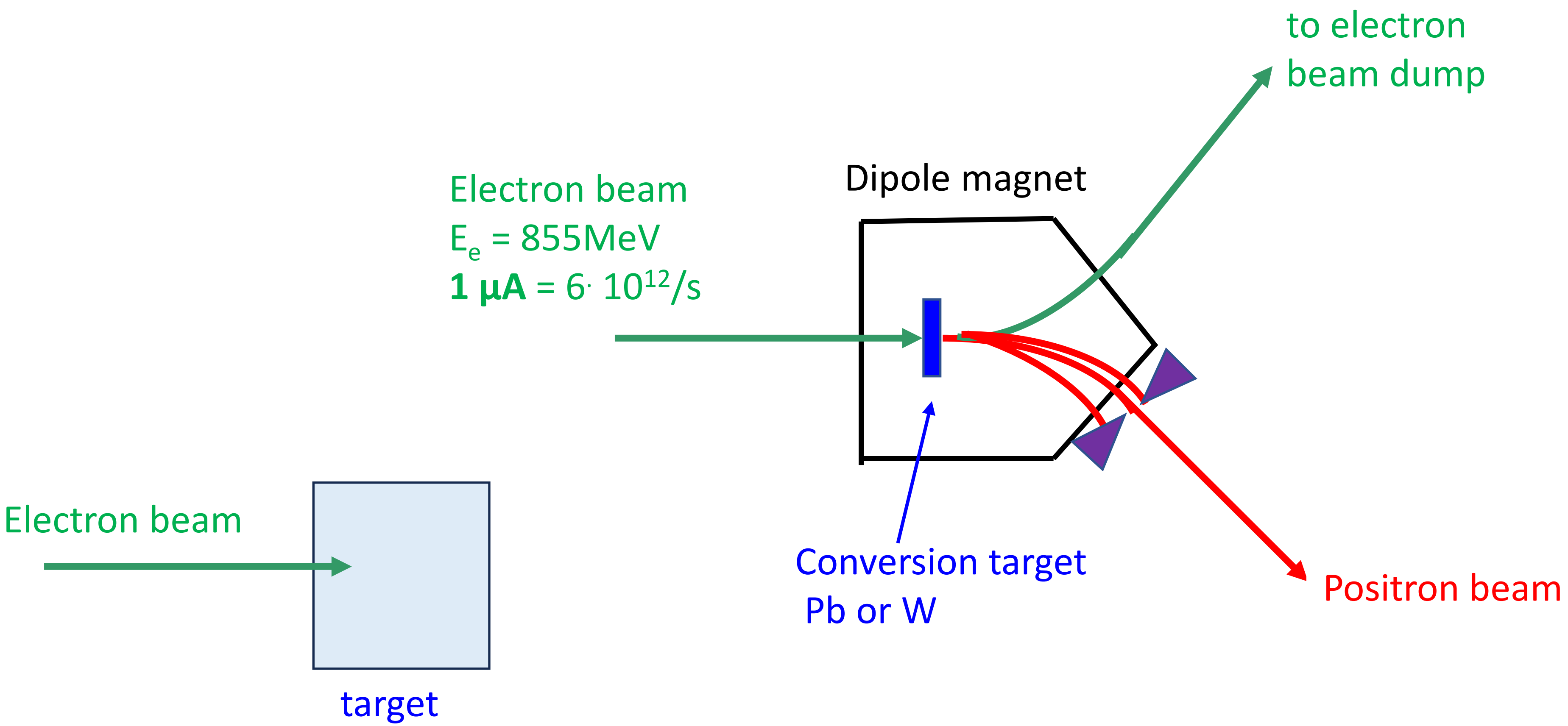
Diamond crystal : 0.31 mm thick , axis <100>

Objective 3.4

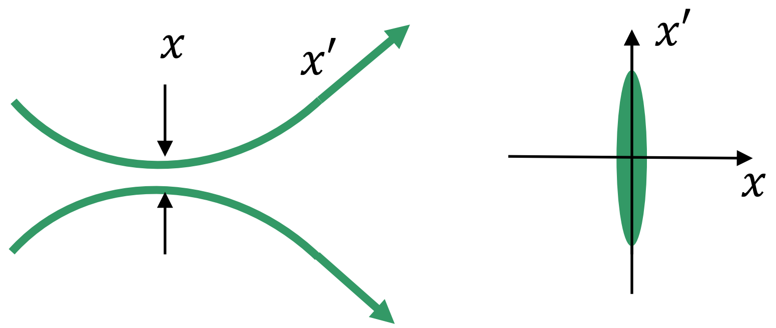
O3.4 Construction of a beam transport system for monochromatic low divergence 600 MeV positrons.

T3.2 (Uni-Mainz, UNIFE, INFN) *Design a setup for direct production of high-energy positrons with bremsstrahlung using the electron beam. Beam transport design for a low divergence positron beam from a conversion target. Radiation shielding simulations**. Experimental validation of the simulations.** Geant4 simulations for a position sensitive particle detector for the identification of positrons. Construction and test of such a detector at MAMI. Development of a low background detector for radiation measurements in the MeV region.*

Pair production with the MAMI beam in combination with a monochromator



High quality Positron beam @ MAMI



vertical

MAMI: $\varepsilon_x = x \cdot x'$

$= 1\, mm \cdot \mu rad$

$= 10\, \mu m \cdot 0.1 mrad$

Emittance $\varepsilon_x = x \cdot x' = \frac{F}{\pi} = const$

Thin target for Positron production

$10\ \mu m\ \ W \ \rightarrow Scattering\ \sigma_S = 0.94\ \mathrm{mrad}$

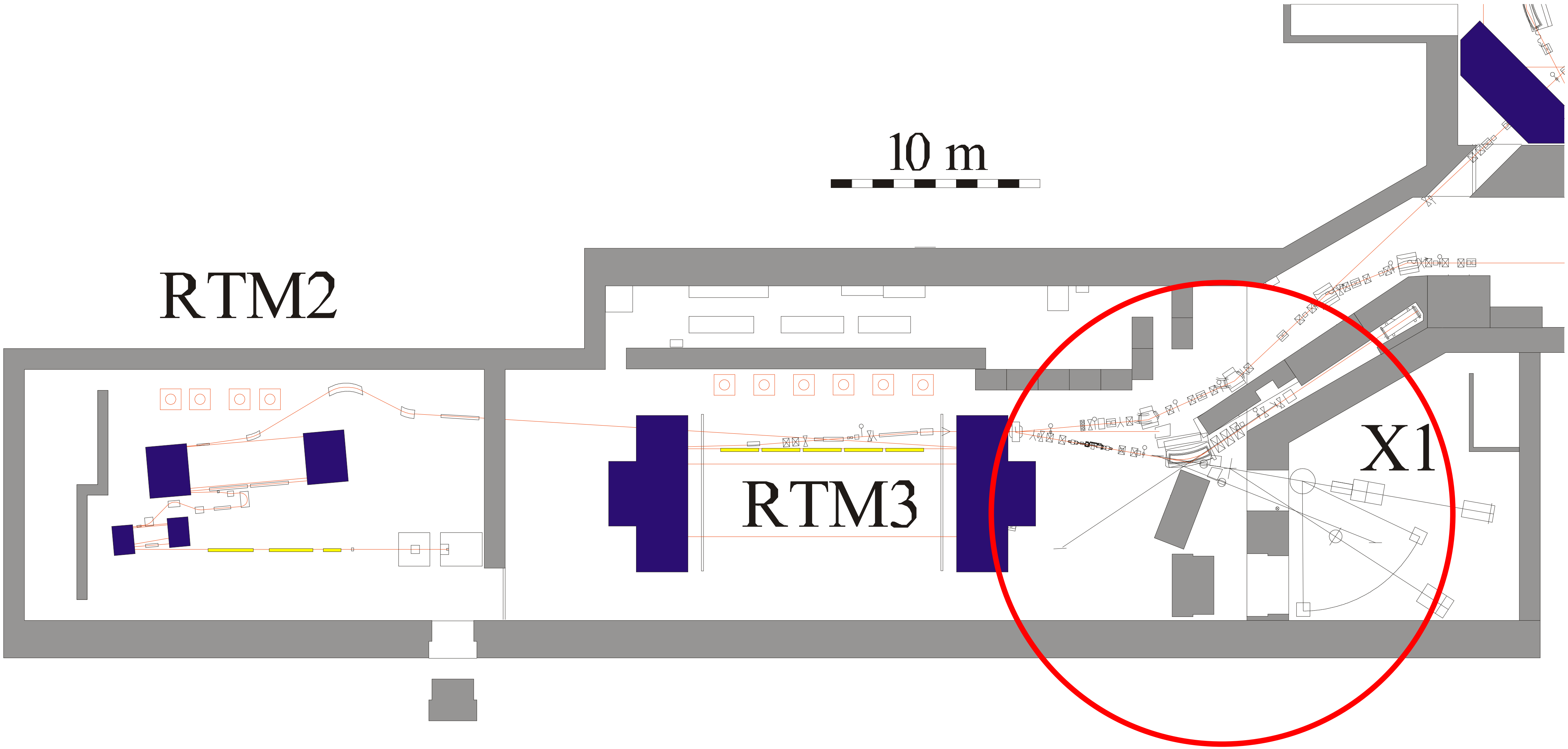
$$\sigma_p = \cong \frac{1}{\gamma} = 1\ \mathrm{mrad}\ @500\mathrm{MeV}$$

Emittance of Positrons:

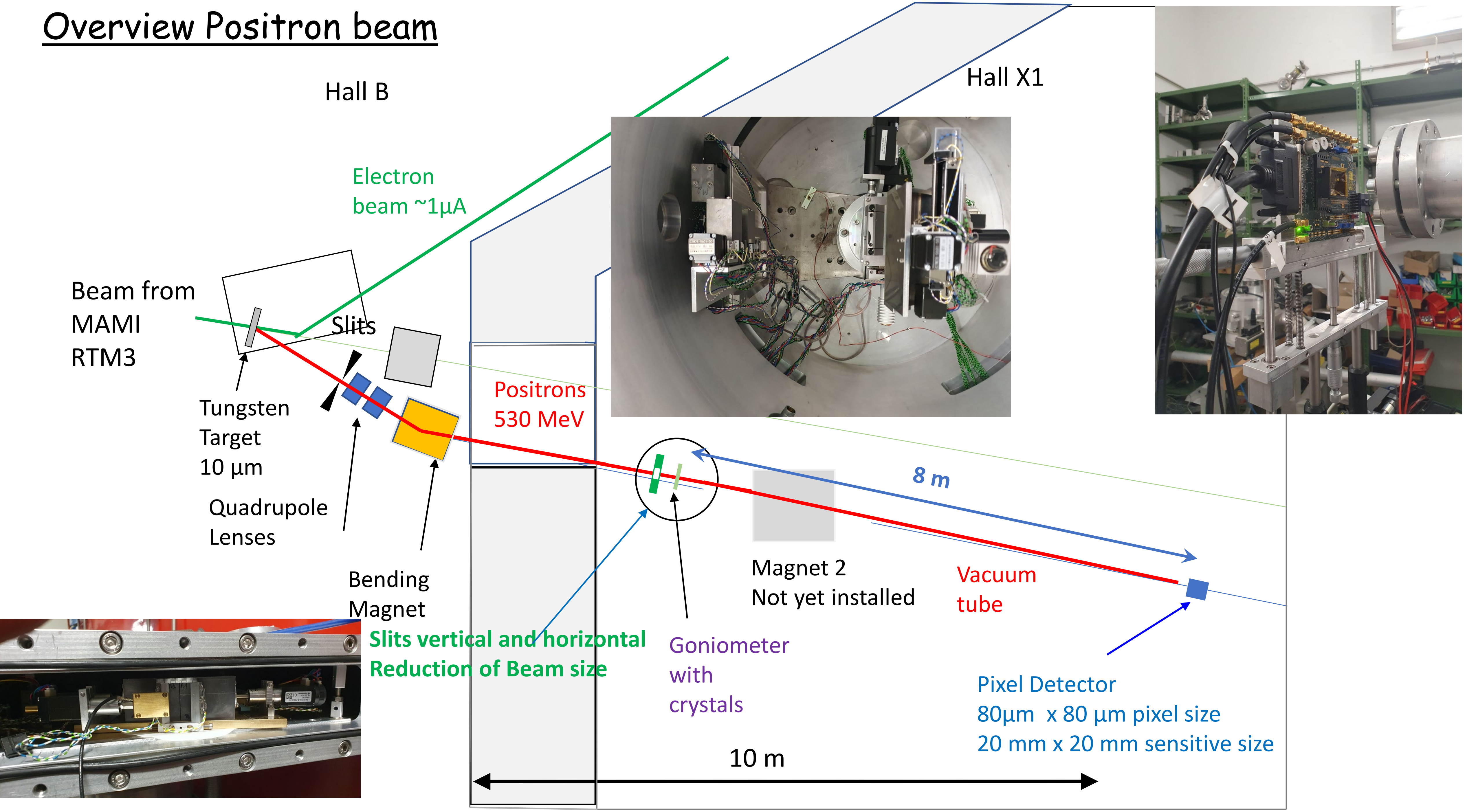
$$\varepsilon_{e+} = 10\ \mu m\ \cdot\ 1.4\, mrad$$

$$= \ 1mm \cdot 0.014\, mrad$$

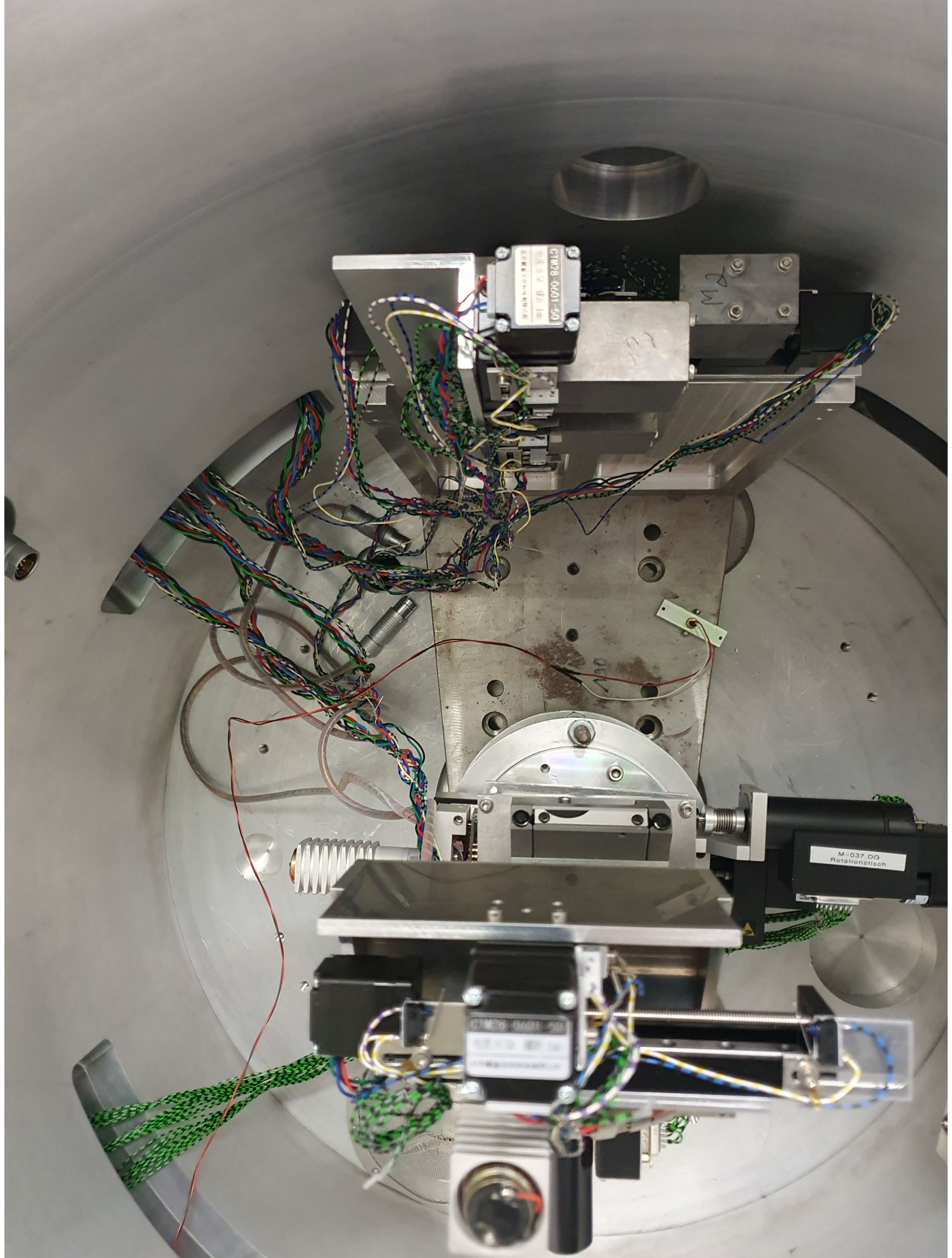
Production of high-energy positrons



Overview Positron beam

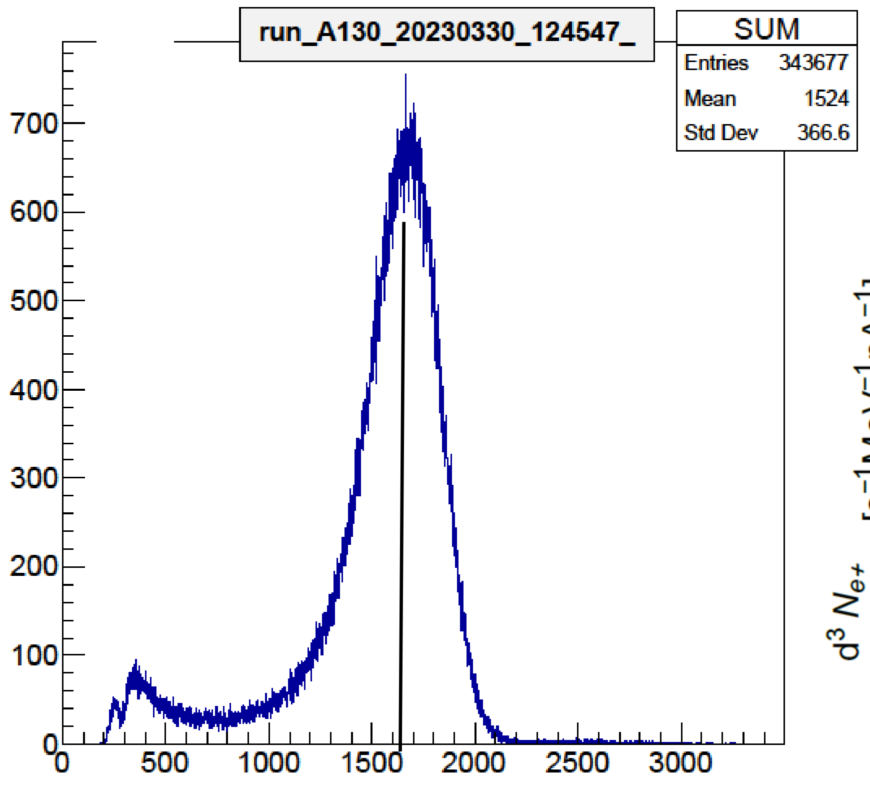



X1

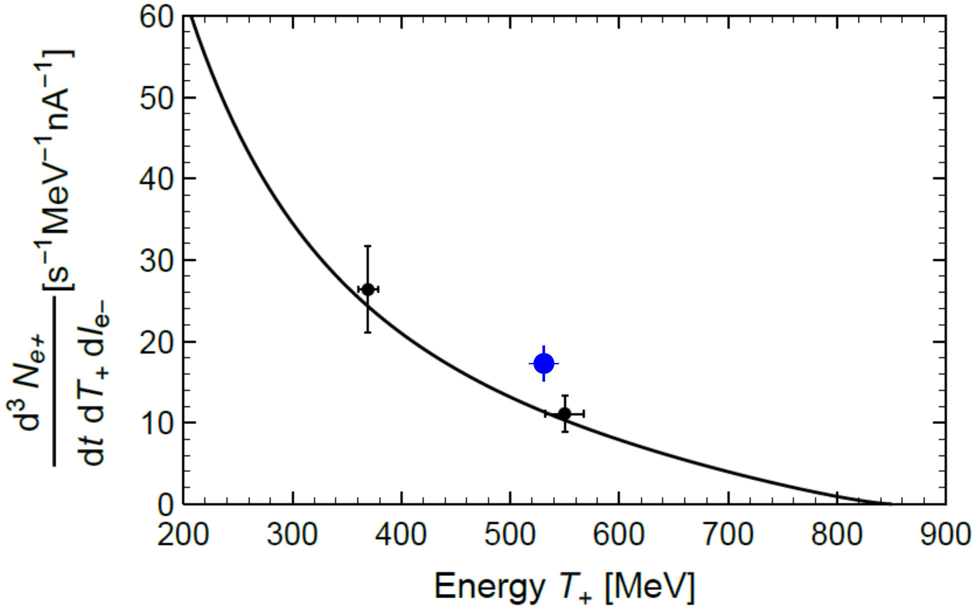

M-037.DG
Rotationstisch

Production Rate

10 μm W Target
Slit width 3mm
~4.5 MeV



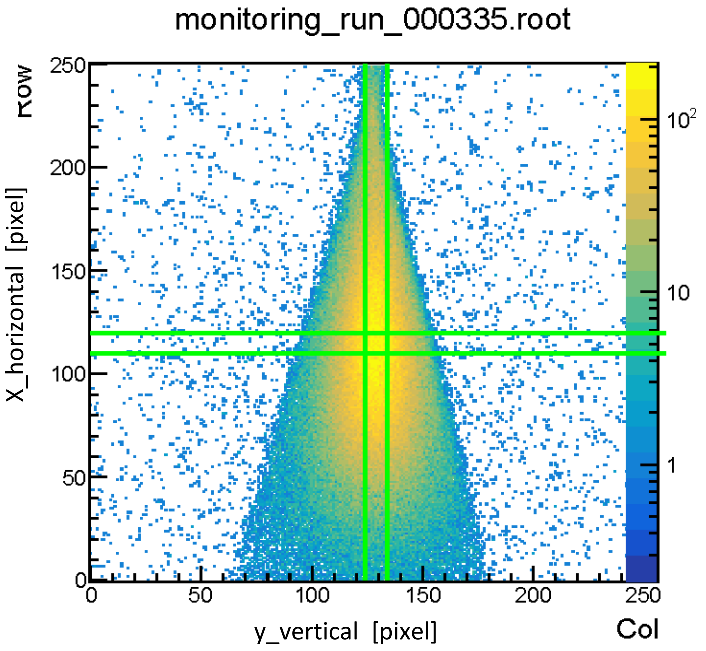
530 MeV

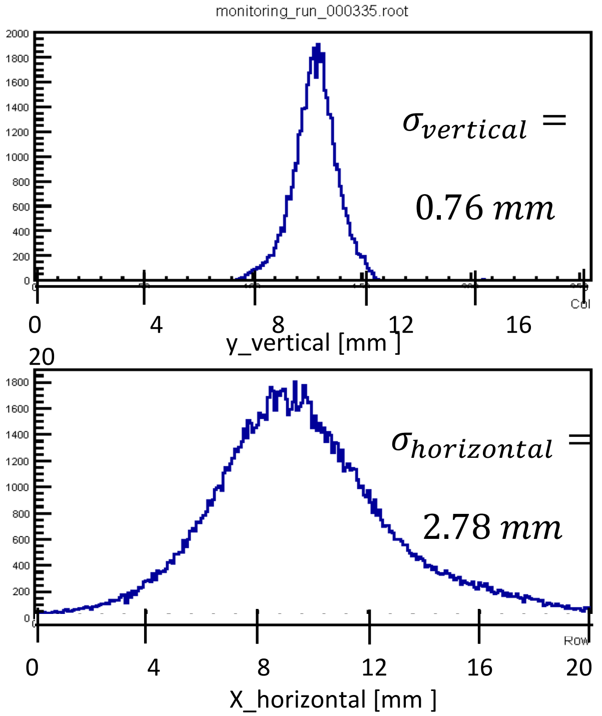


$$17.3 \frac{1}{s \cdot nA \cdot MeV}$$

Max. e-current (without shielding) ~1 μA ->
Max. positron rate **20 kHz**

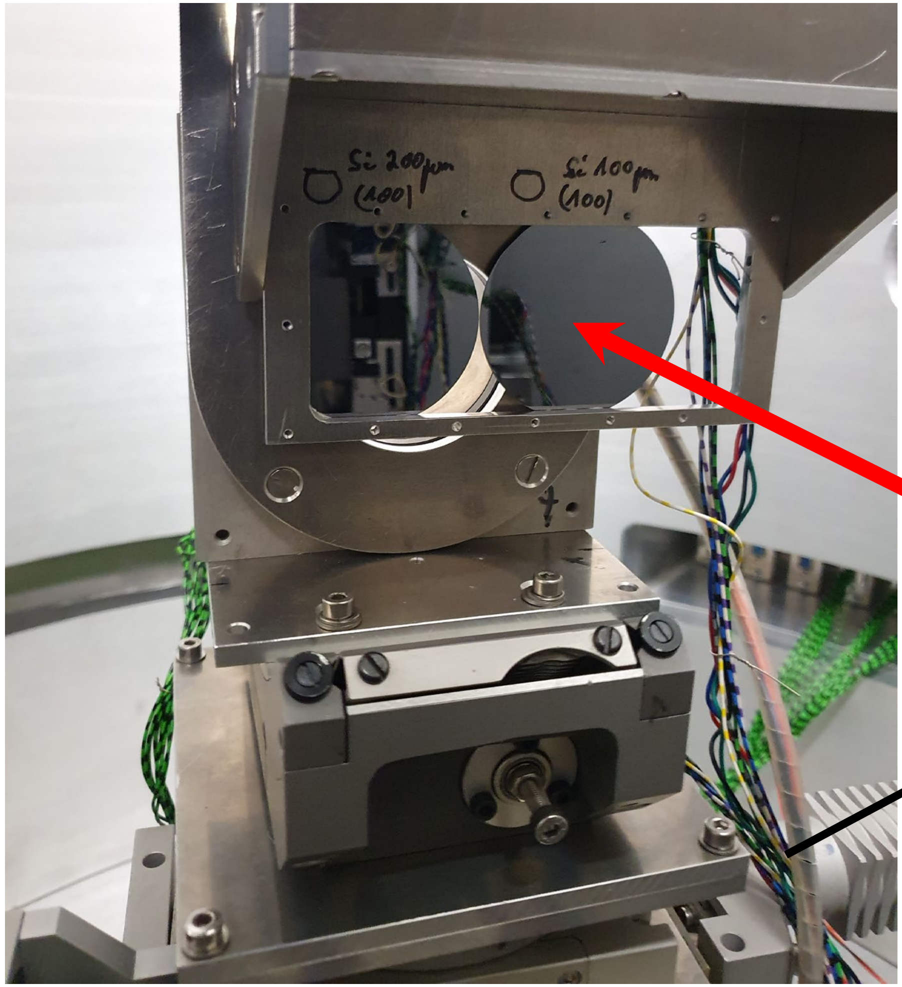
Measurement of the beam size of the focused positron beam with the pixel detector





distance of 1.04 m from the centre of the crystal chamber

Channeling of Positrons in Si crystals

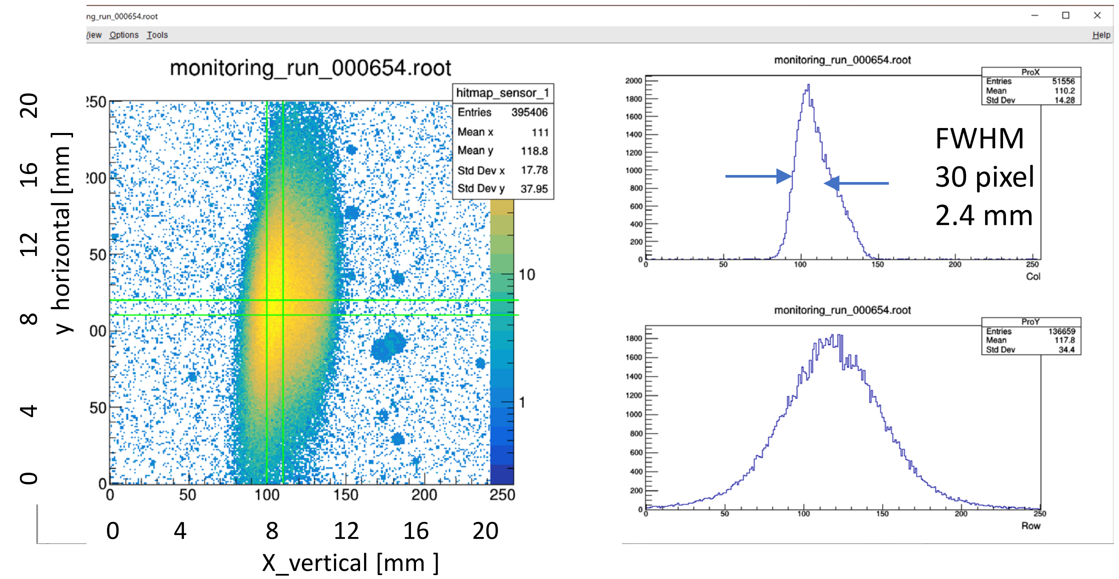


e^+

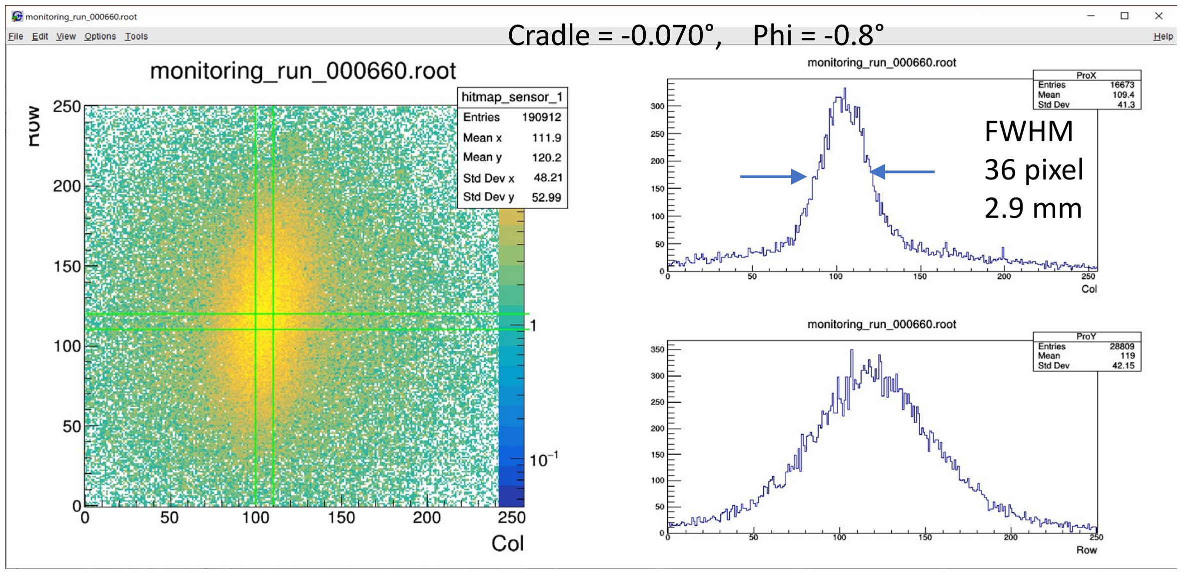
Detection of Positrons with pixel detector

200 µm (100) Si crystal

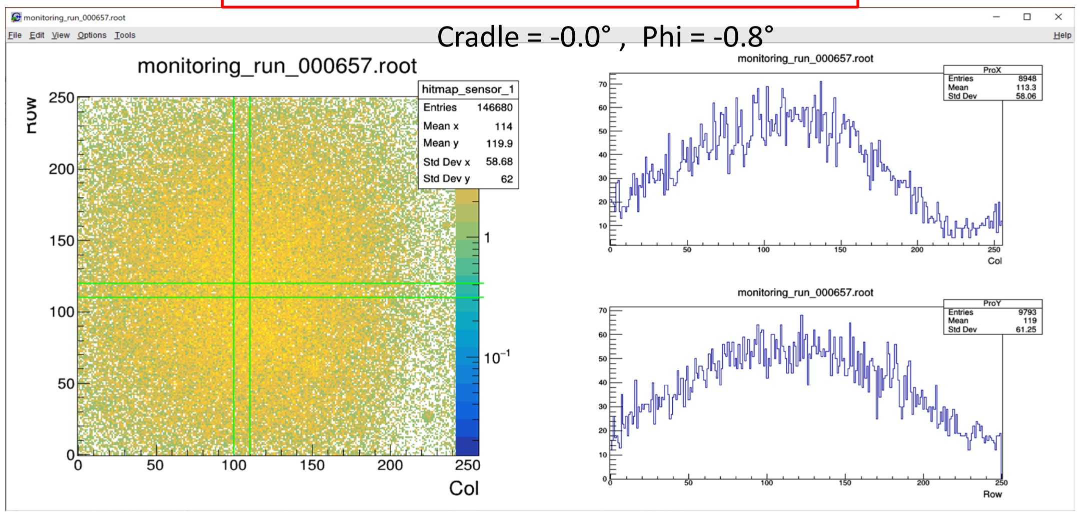
Without crystal

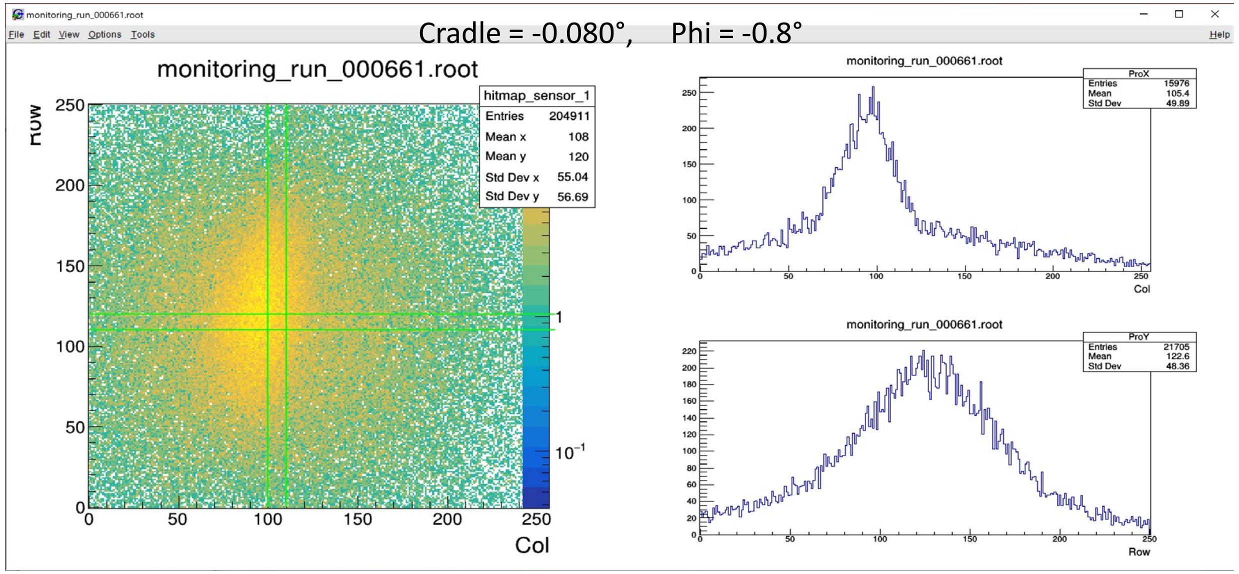


With oriented crystal



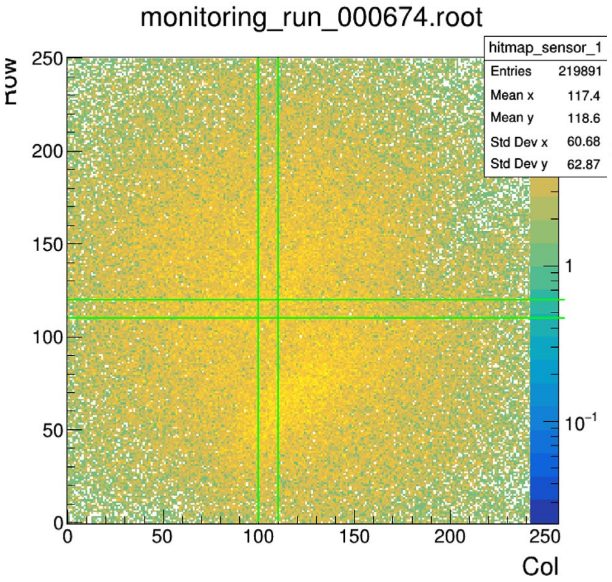
Random orientation of crystal



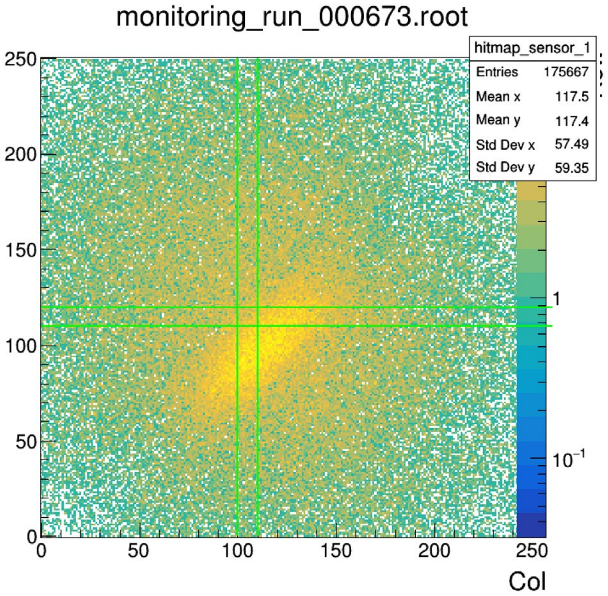


200 µm (100) Si crystal

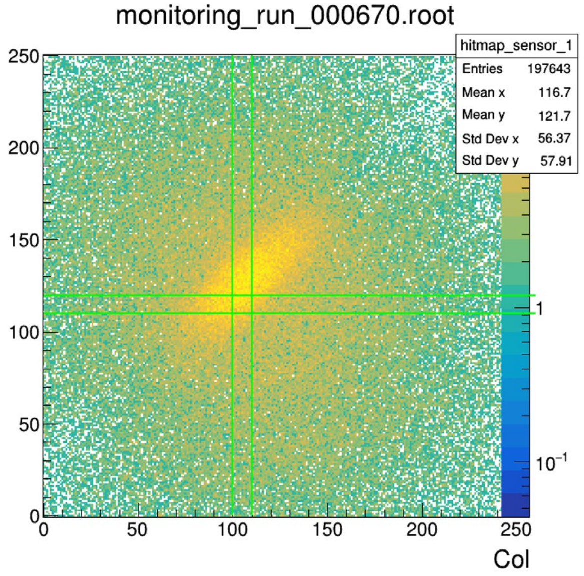
110 Plane
Rotation arround vertical axis



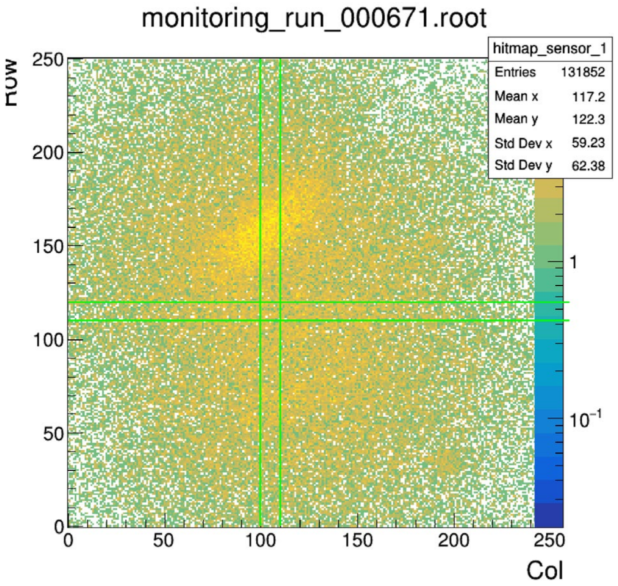
Cradle = -0.2°
Phi = -0.11°



Cradle = -0.2°
Phi = -0.13°

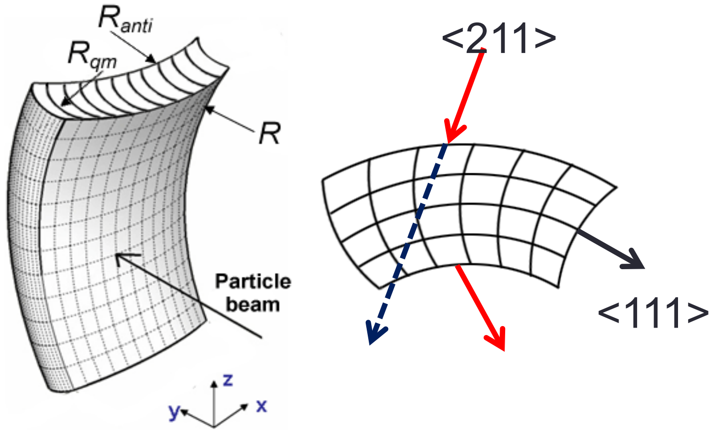


Cradle = -0.2°
Phi = -0.15°

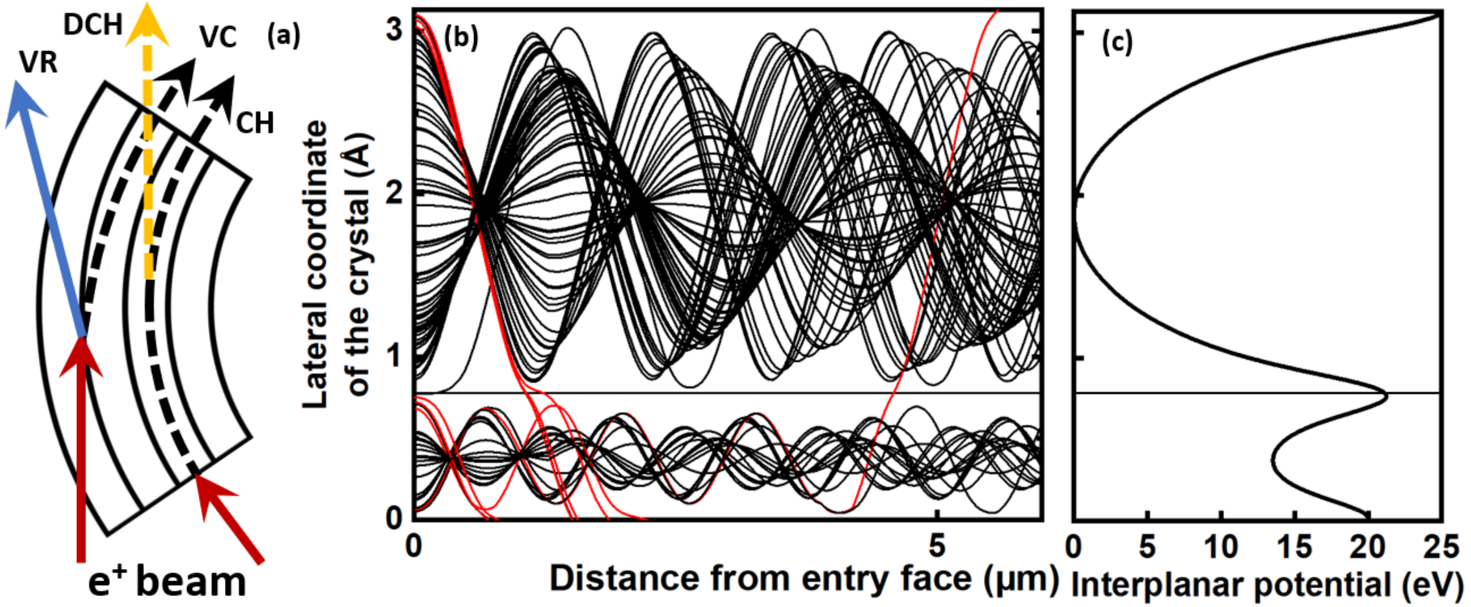


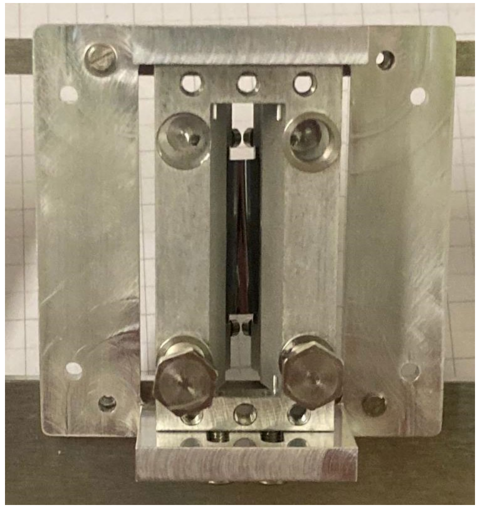
Cradle = -0.2°
Phi = -0.17°

Mechanically bent Si crystal test with 530 MeV positrons



Guidi, V., et al.,, 2009. Journal of Physics D Applied Physics42(18).
Germogli, G.,NIM B, 2015. 355: p. 81-85





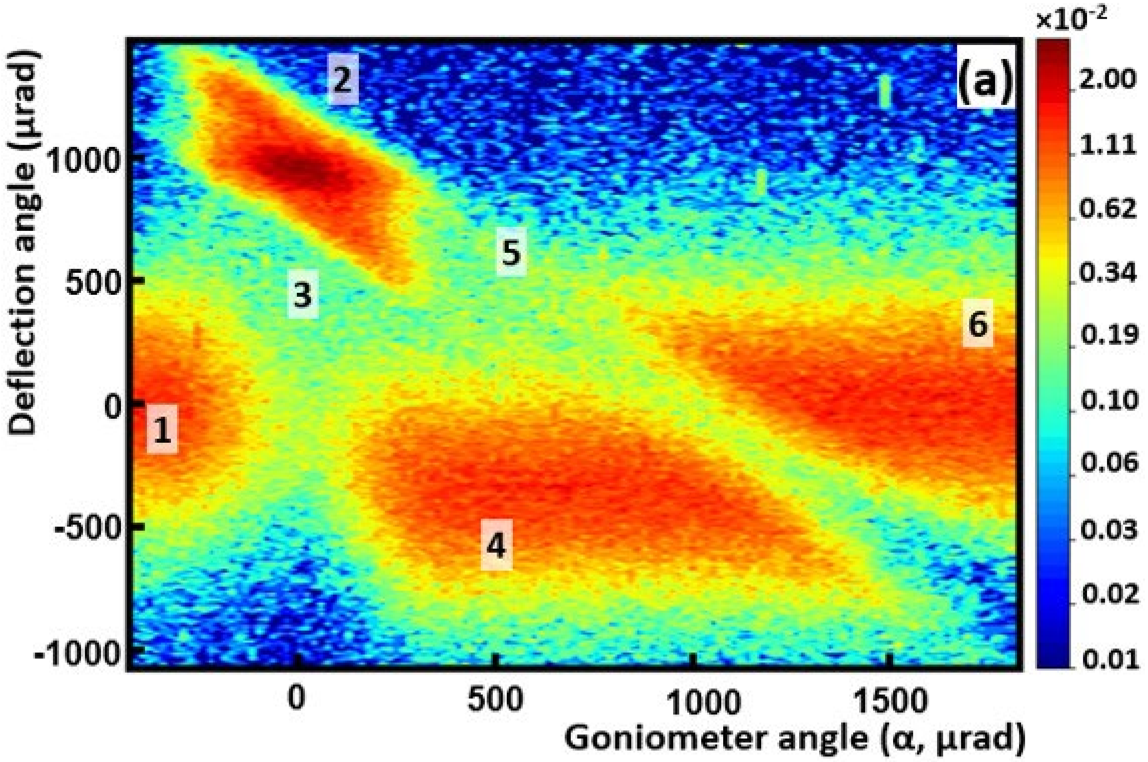
Crystal label: BC-Si-QMO*
Thickness along the beam: 29.9±0.1 μm Bent planes, exploiting quasimosaic effect (111)
Bending angle: 970±10 μrad

Crystal available from a previous project @

INFN Istituto Nazionale di Fisica Nucleare

FERRARIAE UNIVERSITAS · 13 91 · EX LABORE FRUCTUS

Experimental results on beam steering of 530 MeV positrons



Mazzolari, A., Backe, H., Bandiera, L., et al., (2024)
arXiv:2404.08459

TECHNO-CLS MILESTONE:
First high-efficient deflection of sub-GeV positron worldwide !!!

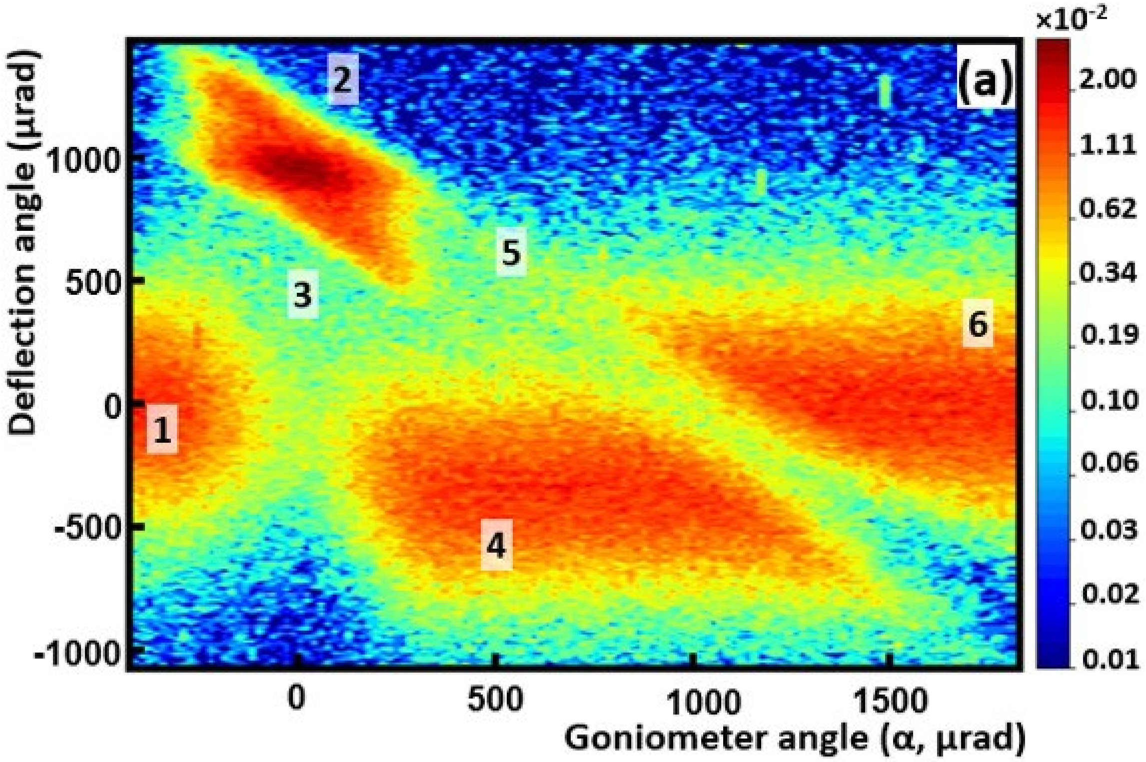
Fallout in :

- ❑ Crystal-Light-Source
- ❑ Channeling based technologies
- ❑ Accelerator technologies: for beam steering, extraction, focusing..

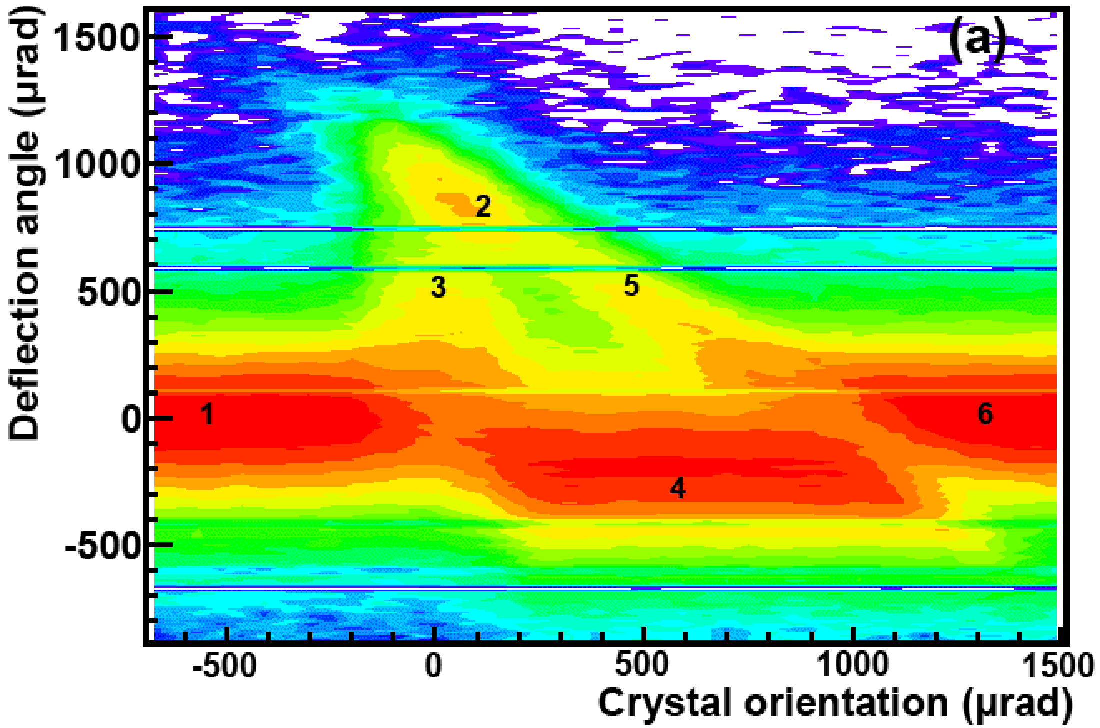
Open access paper on arXiv
Submitted to Phys. Rev. Lett.

530 MeV positrons* vs 855 MeV electrons**

Angular scan for deflected beam distribution: (1) and (6) nonchanneling regime; (2) channeling; (3) dechanneling; (4) volume reflection; and (5) volume capture.



*Mazzolari, A., Backe, H., Bandiera, L., et al., (2024) arXiv:2404.08459



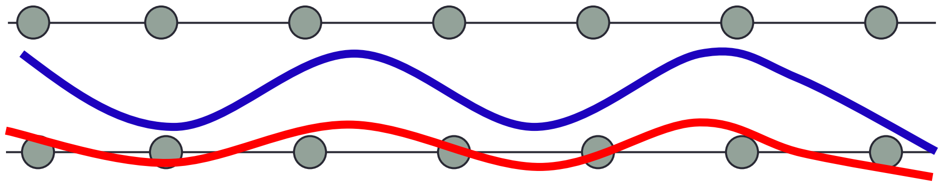
**Mazzolari A., Bagli E., Bandiera L., et al., Phys. Rev. Lett. 112 (2014) 135503

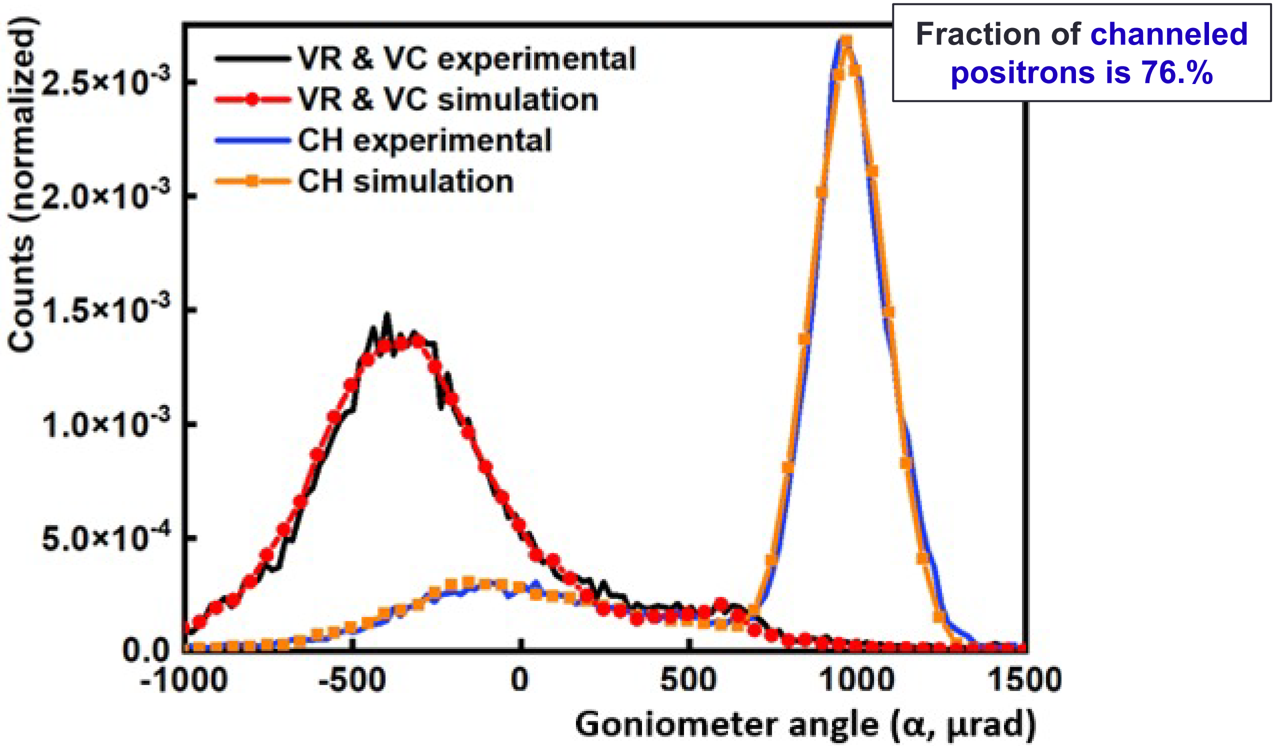
Channeling efficiency e+ vs e-

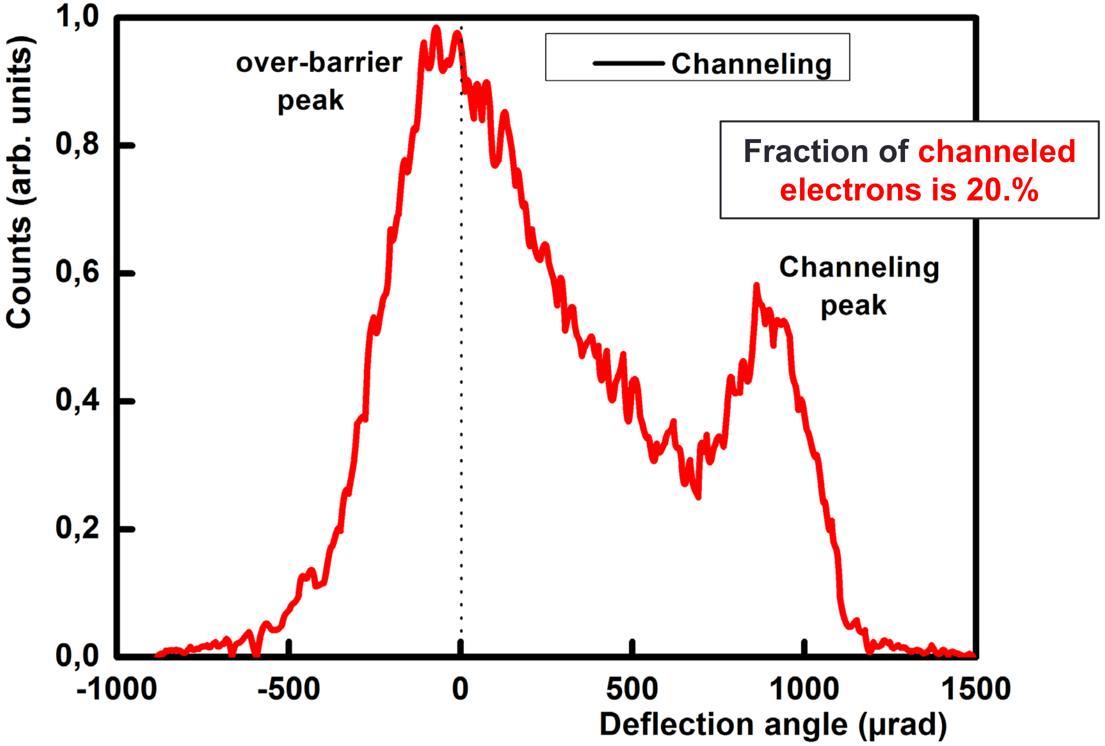
Advantage of positrons for CLS –> higher channeling efficiency!

positron

electron



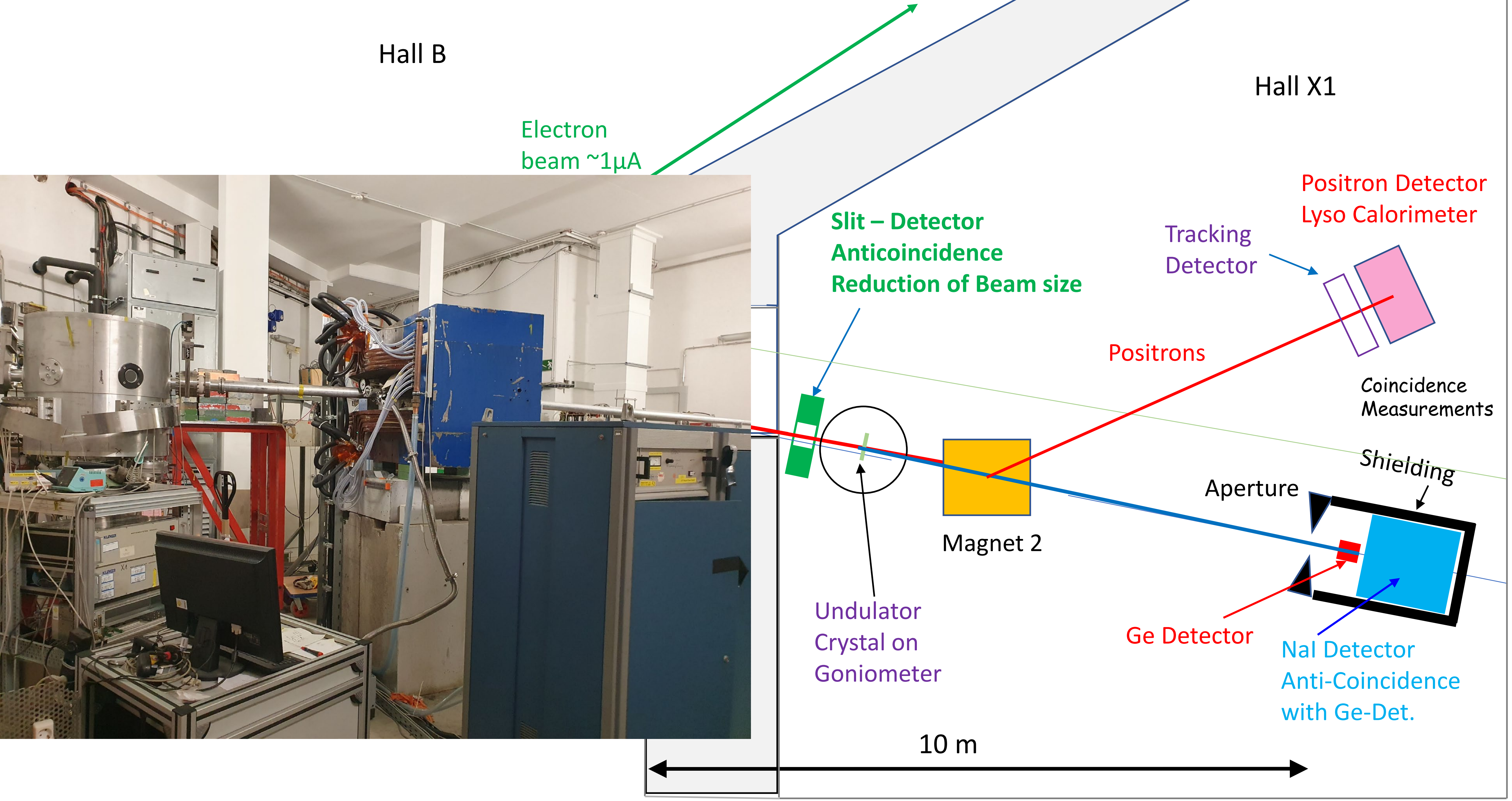




*Mazzolari, A., Backe, H., Bandiera, L., et al., (2024) arXiv:2404.08459

**Mazzolari A., Bagli E., Bandiera L., et al., Phys. Rev. Lett. 112 (2014) 135503

Overview Positron beam line –next steps



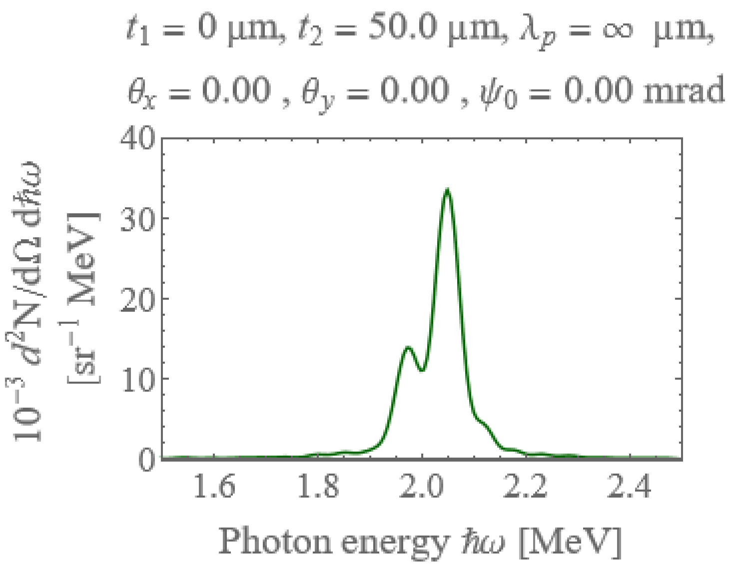
Future experiments with the Positron beam line

- Deflection of positrons (√)
- Channeling radiation with positrons /Tagging of channeling radiation
- Characterization of CLS Prototypes
- Dechanneling length measurements
- Undulator radiation with periodically bent crystals

Count rate estimation for channeling radiation

Calculation H. Backe et al., arXiv:2404.15376

- Positron rate: ~$2 \cdot 10^4$ Positrons/s
- Reduction of beam spot size 2mm
  -> 5000 Positrons/s
- Solid angle $3 \cdot 10^{-7}$ sr
  (d=4mm, Distance 6m)
- Integral Channeling photons~ 3000/ (e^+ sr)



Total Count Rate = Photons/(e^+ sr) · Solid angle · Positrons/s

= 3000/ (e^+ sr) · $3 \cdot 10^{-7}$ sr · 5000 e^+/s

~ 5/s

Thanks for your attention

TECHNO-CLS

Horizon Europe EIC-Pathfinder Project TECHNO-CLS: "Emerging technologies for crystal-based gamma-ray light sources"

MBN Research Center

Università degli Studi di Ferrara
- EX LABORE FRUCTUS -

University of Kent

Hellenic Mediterranean University

ESRF

INFN
Istituto Nazionale di Fisica Nucleare

Università degli Studi di Padova

Johannes Gutenberg Universität Mainz
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