Review of experiments on positron production from crystal targets at KEK

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Introduction

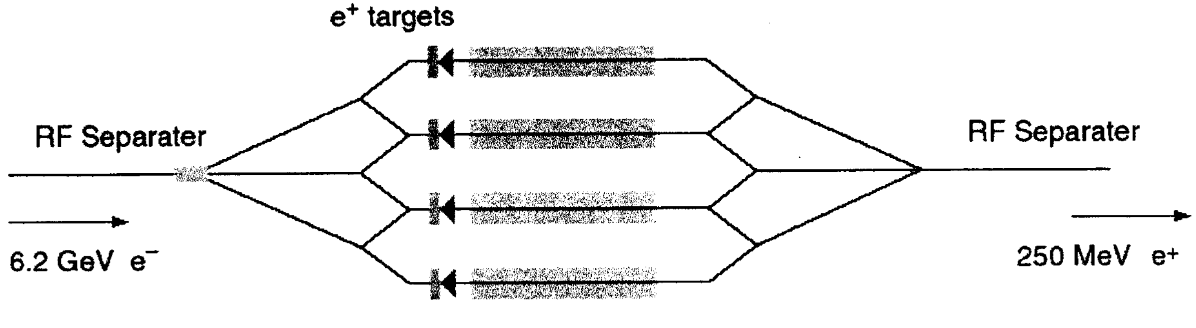
- Intense positron sources are required for
  - e^+- e^- Linear colliders
  - high luminosiy B-factory
- Linear collider projects require more positron

Project	Flux(e^+)	Q(J/g)	P(kW)
CLIC	1.0×10^{14}	65	22
NLC	1.8×10^{14}	40	16
JLC	2.2×10^{14}	140	49
Tesla	2.8×10^{14}	222	5

Quoted numbers are taken from the T4-report/Snowmass 2001

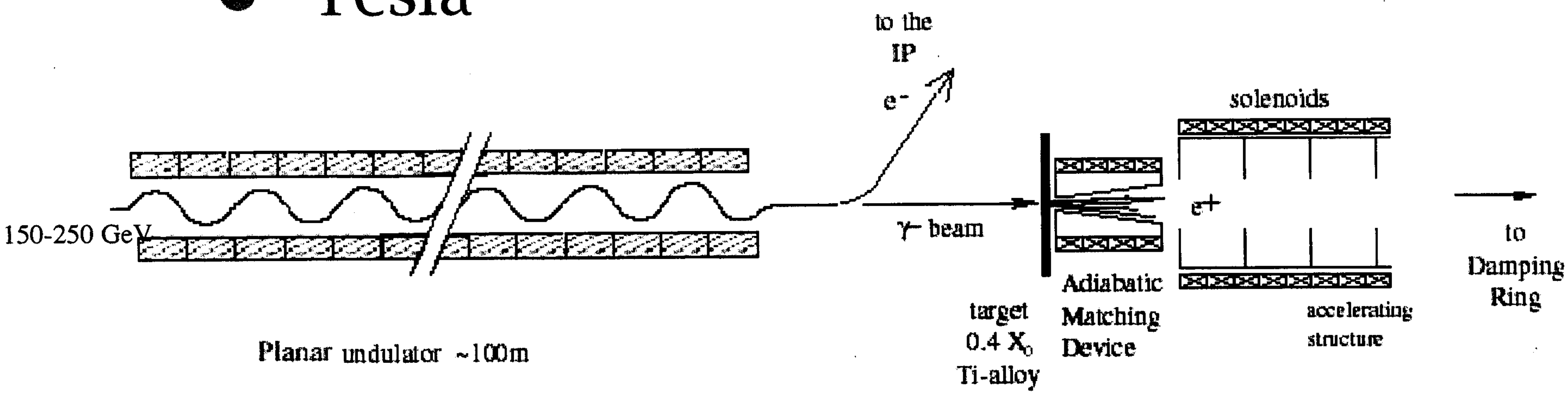
Introduction (continued)

- Proposed design
  - NLC



3 out of 4 target system scheme

  - Tesla

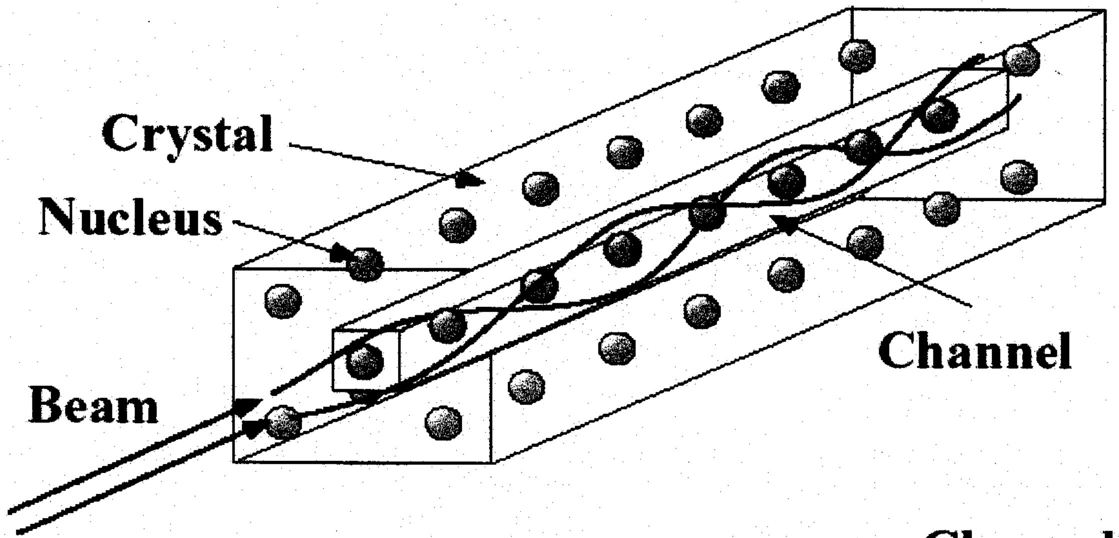


Figures from the T4-report/Snowmass 2001

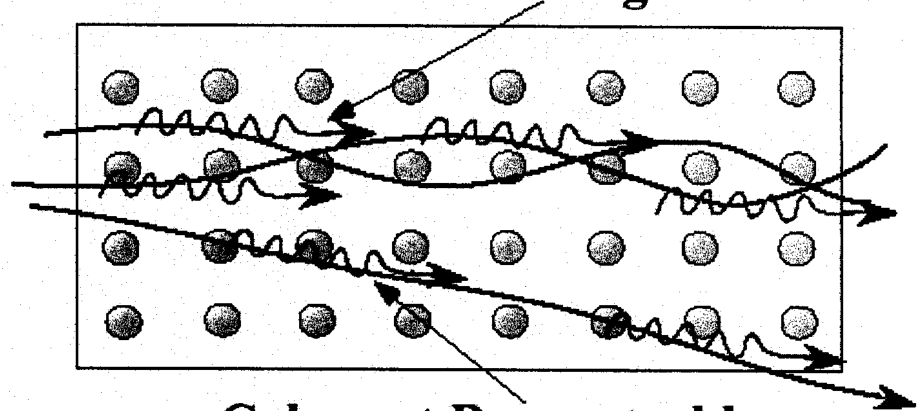
Positron source using oriented crystals

- Oriented crystal plays an atomic undulator
- Coherent generation of photons yields more positrons than amorphous with the same thickness
- Need to study: optimum thickness crystal/amorphous combination

Channeling and Coherent Bremsstrahlung



- In single crystal these two phenomena enhance e.m. shower (photon) and positron yields

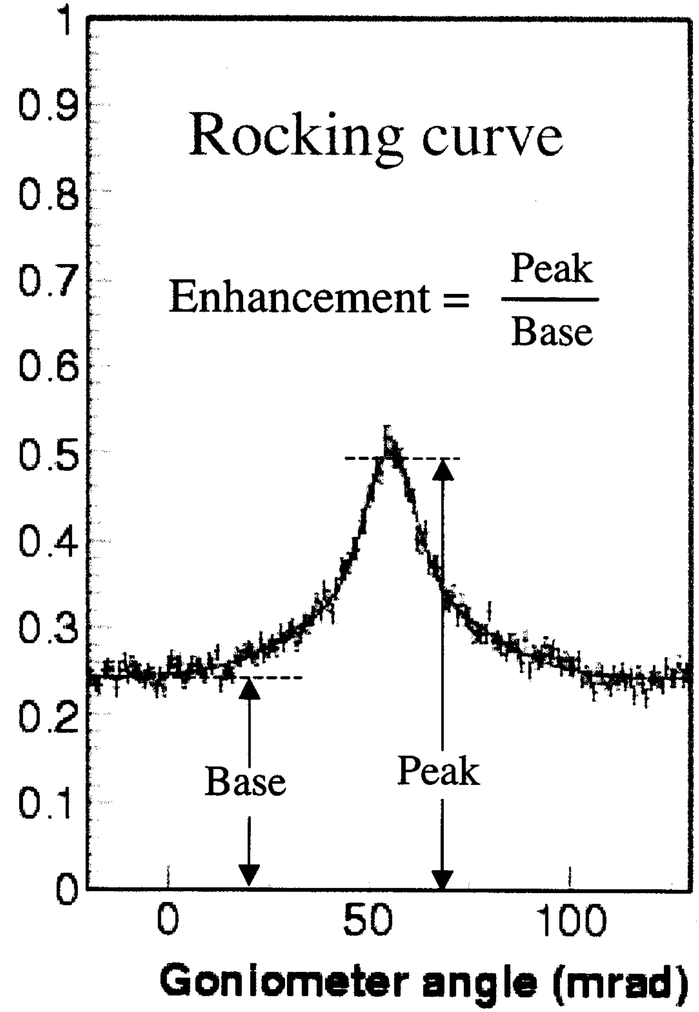


Experimental investigations

- Proof-of-principle experiments
  - Orsay in 1992-93
  - INS-Tokyo at 1.2 GeV in 1996
    - ✓ 3 times more positrons from 1.2 mm thick W-crystal in 10-20 MeV/c momentum range
- More detailed experiments at ~1 GeV in INS-Tokyo (~1999)
- Experiments at higher electron energies using KEK-B injector linac (2000~)

Experiments at INS-Tokyo

- Proof-of-principle experiment
  - Rocking curve: e+ yield as a function of crystal angle
  - ~3times more positrons from W crystal (1.2mm) at 1.2GeV
- More detailed experiments at INS-Tokyo in ≦1 GeV region



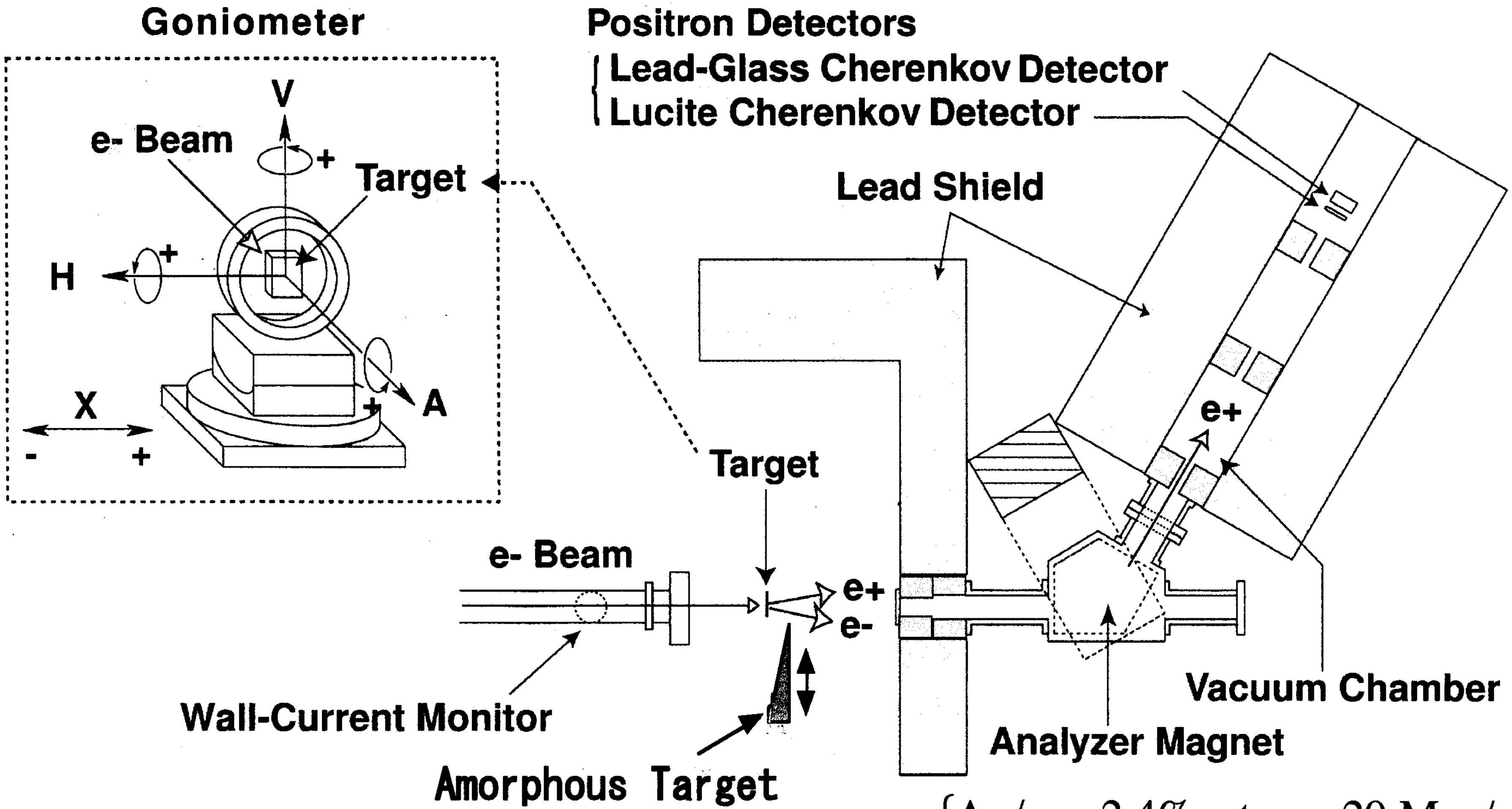
Experiments at INS-Tokyo (cont.)

- Enhancement factor of 2.3 for 1.2mm thick W crystal with <111> axis at 1 GeV
- More enhancement at higher energies
- Angular widths of the rocking curves are much wider than the Lindhard angle
- Rocking curves are explained well by the coherent Bremsstrahlung (CB)
- Angular and momentum distributions of positrons are about the same for on- and off-axis conditions

Experiments at KEK

- Beam energy 4 and 8GeV @KEK-Linac
- Positrons with $p = 5\sim20$ MeV/c
  - Rocking curves/Crystal orientation
  - Crystal thickness
    Tungsten W (2.2, 5.3, 9.0 mm)
  - Other crystals
    Diamond (5mm), Silicon(10, 30, 50mm)
  - And combination with amorphous
    Tungsten (3, 6, 9, 12, 15, 18 mm)

Experimental Setup



$$\begin{Bmatrix} \Delta p / p = 2.4\% \;\; \text{at} \;\; p = 20 \text{ Mev/c} \\ \Delta\Omega = 1 \text{ mstr.} \end{Bmatrix}$$

Experimental conditions

■Beam

- Energy: 4 and 8 GeV
- S-band single bunch, pulse width 10ps
- Repetition: 2 ⇨ 25 Hz
- Beam intensity: 1.3×10^{9} e^{-}/bunch (0.2nC)
- Transverse beam size: 1-1.5 mm dia.
- Angular spread: 0.2 and 0.1 mrad for 4 and 8 GeV due to the multiple scattering in the beam window (100 μm thick stainless steel ⇨ 30 μm)

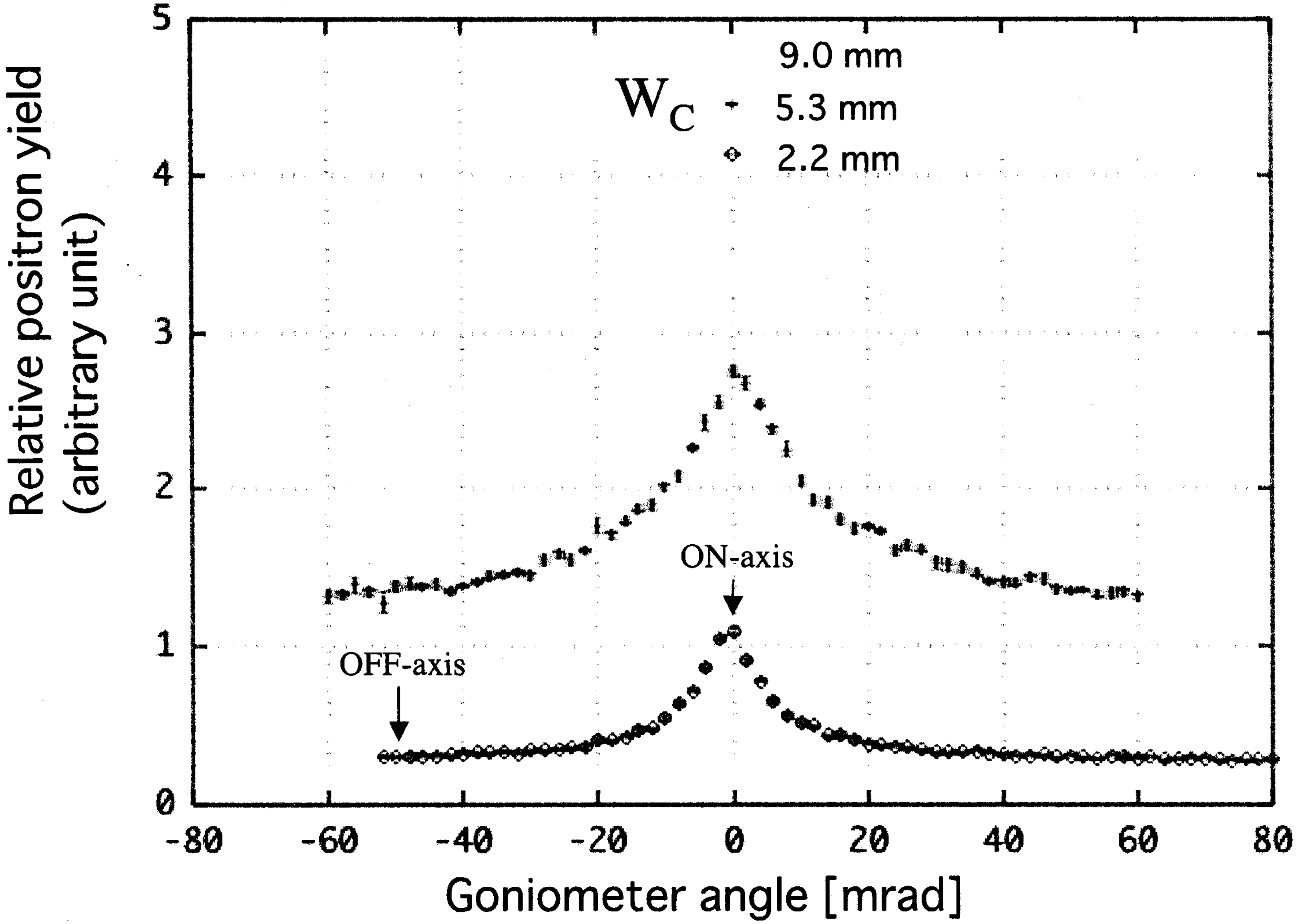
Experimental conditions (cont.)

- Crystal targets

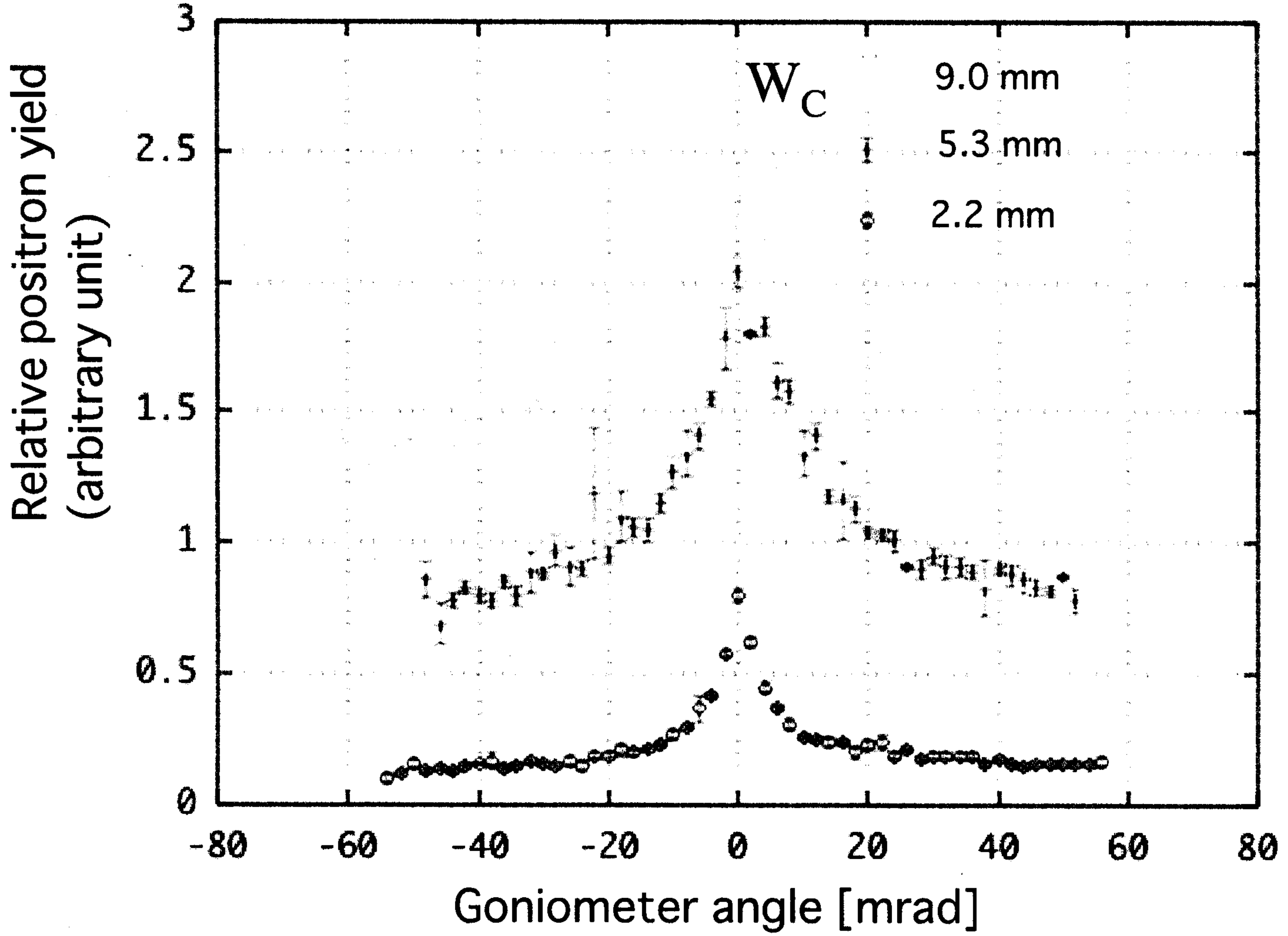
Material Orientation	Thickness mm (rad. lengths)	Mosaicity mrad
Tungsten <111>	2.2 (0.63) 5.3 (1.51) 9.0 (2.57)	1.5 0.5 0.5
Diamond <110>	4.6 (0.037)	0.04
Silicon <110>	10 (0.025) 30 (0.32) 50 (0.51)	not measured

- Amorphous W-targets
  0, 3, 6, 9, 12, 15, 18 mm on the target stage

Rocking curves at 4 GeV

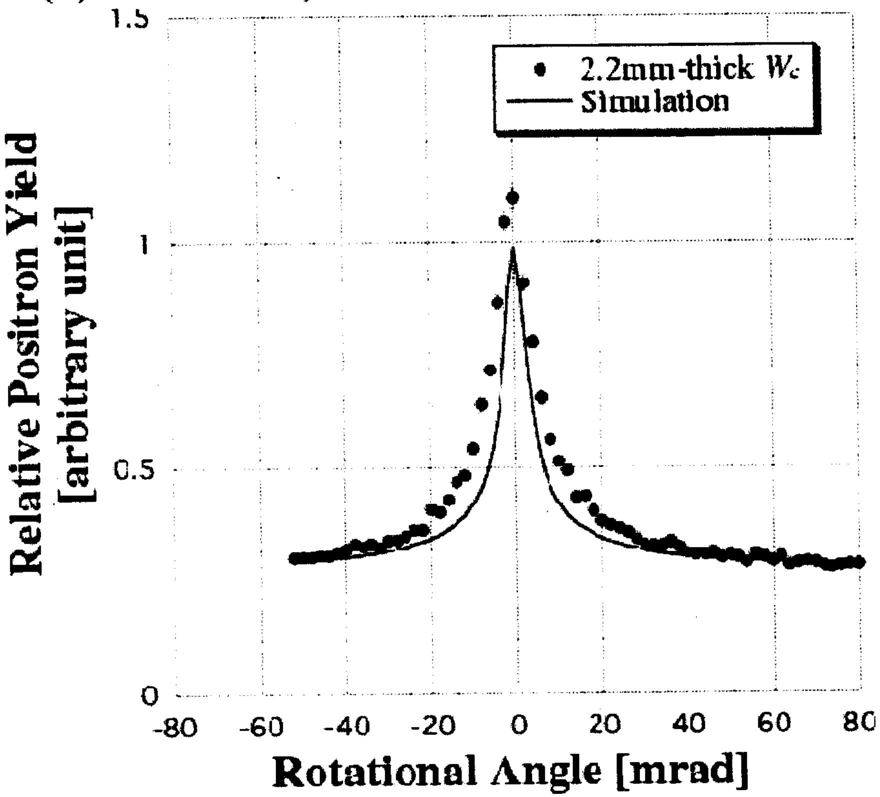


Rocking curves at 8 GeV

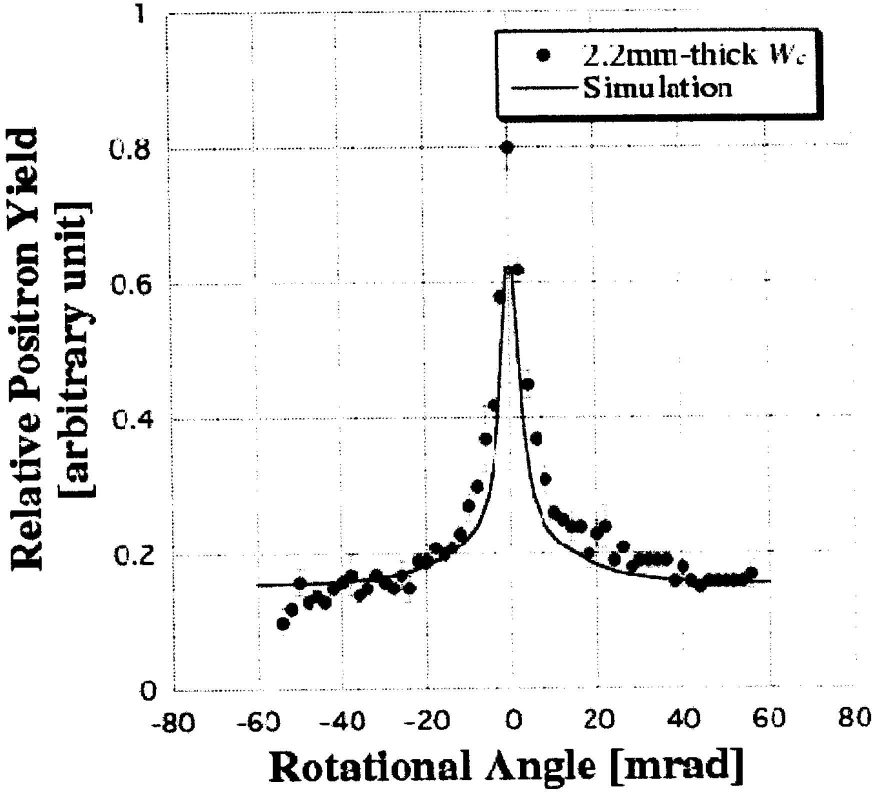


Simulation of CBS with EGS4

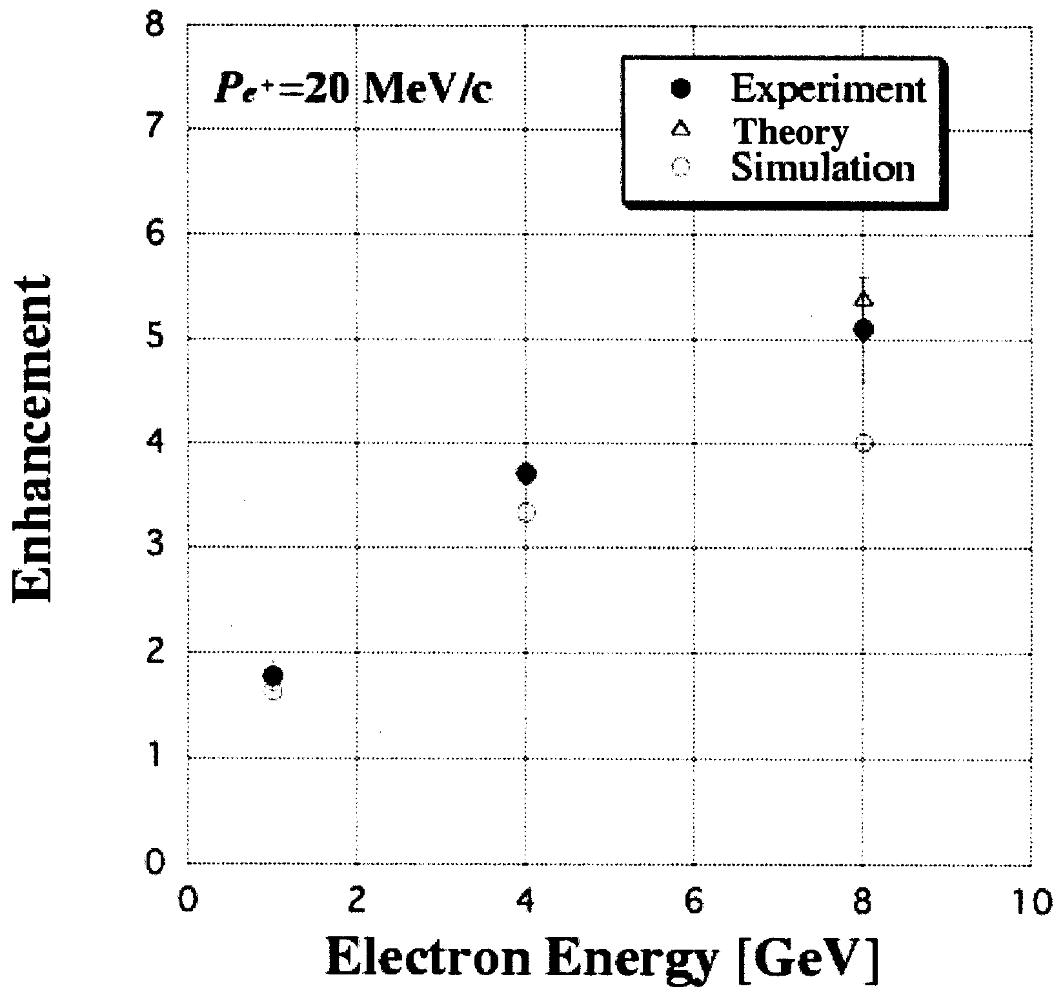
(a) E_{e-}=4GeV, P_{e+}=20MeV/c



(d) E_{e-}=8GeV, P_{e+}=20MeV/c



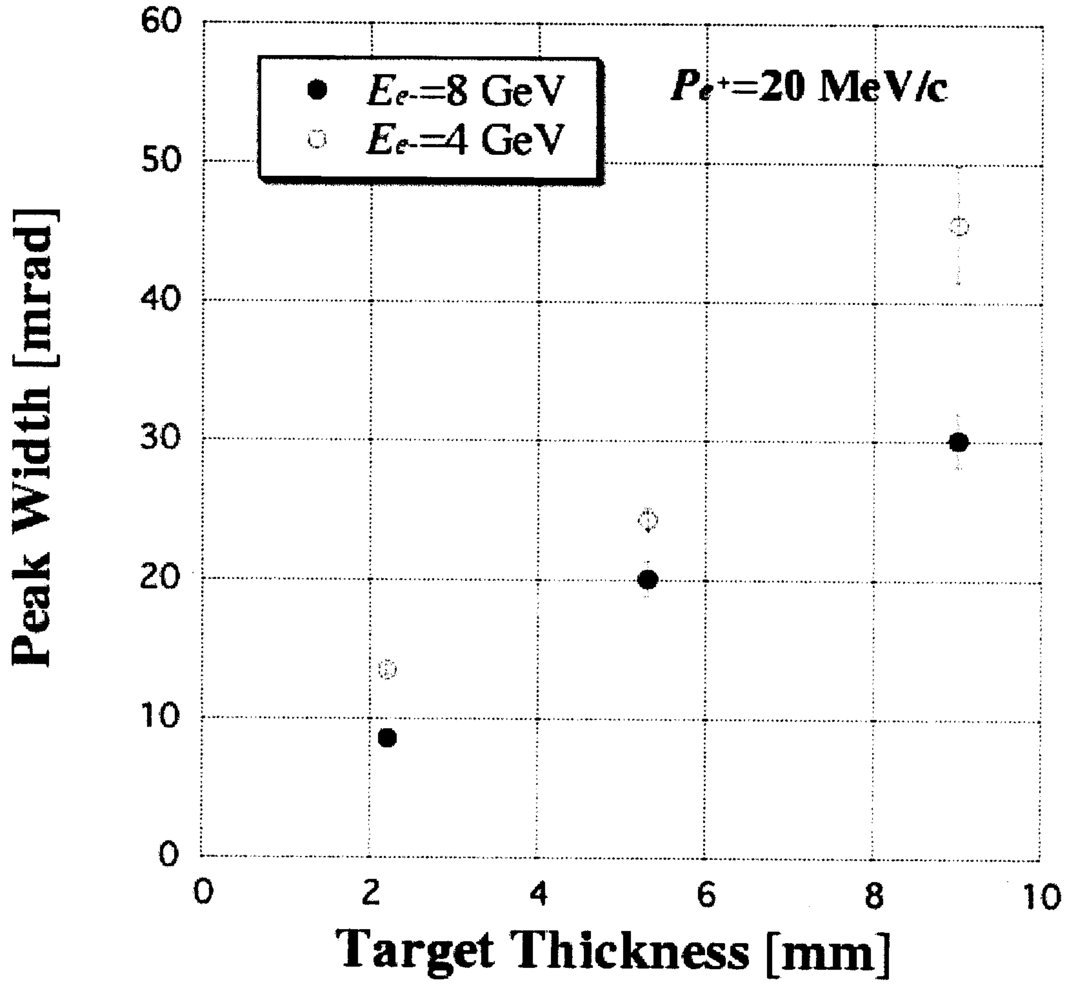
Enhancement v.s. electron energy



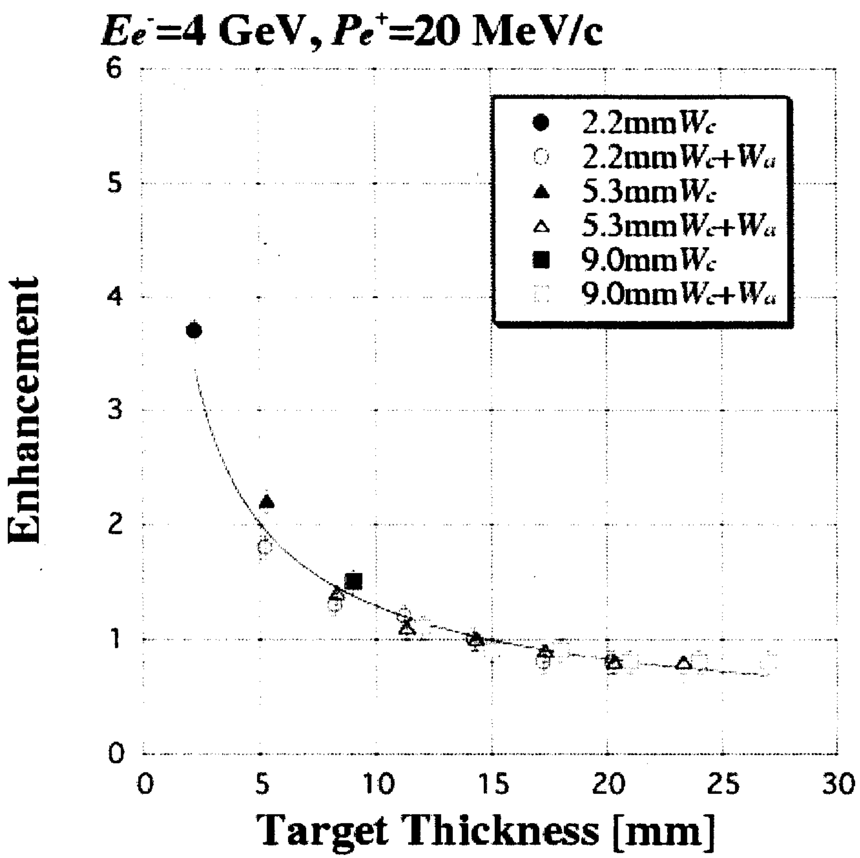
2.2 mm Wc

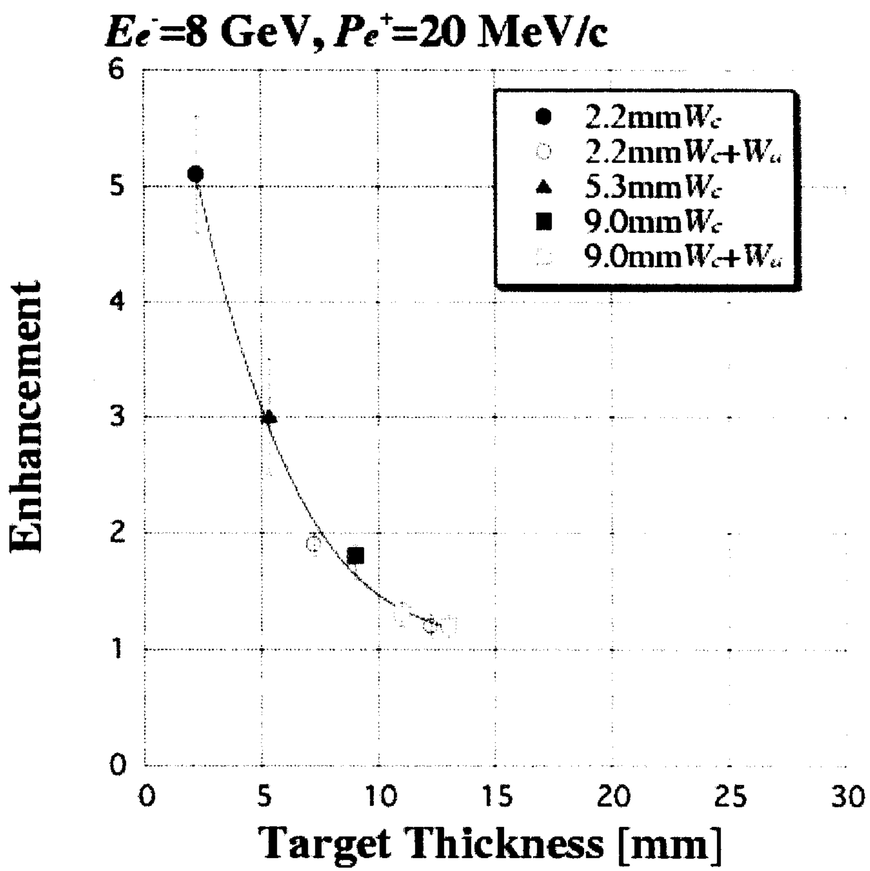
△ Baier and Strakhovenko

Peak width v.s. crystal thickness

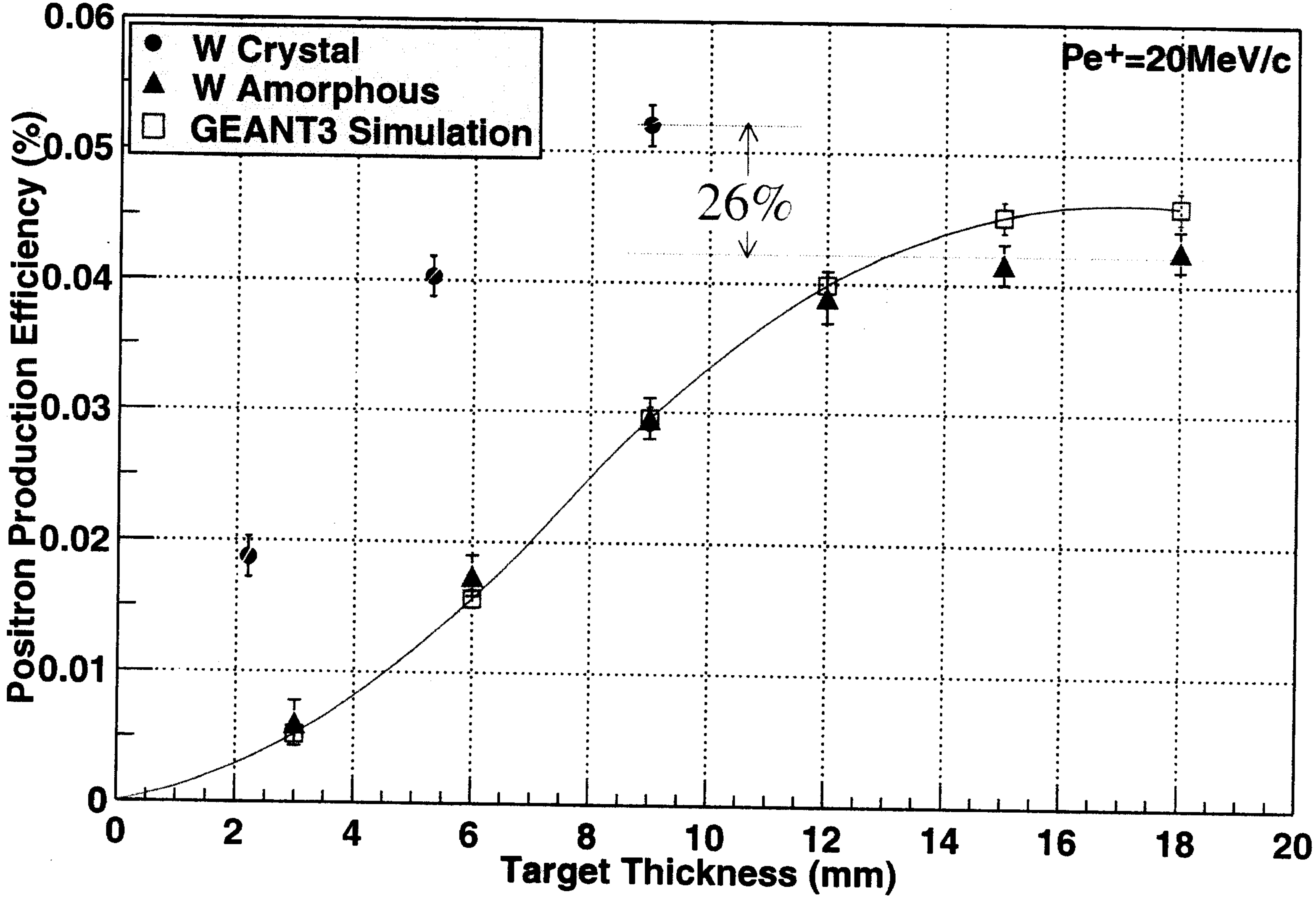


Combination of crystal + amorphous





Crystal v.s. Amorphous at 8GeV



Diamond target

- Diamond is known to be the best crystal for producing intense CB photons

- Thermal conductivity is very high;
  660 W/m/K >> 170 W/m/K for tungsten
  Good for heat dissipation

- Seems high tolerance against the radiation damage;
  there is an estimate up to 10^{20} e^-/cm^2

◆Need to check

Summary

- W crystals
  1. Angular widths of rocking curves; much larger than the channeling critical angles
  2. Enhancement factor increases with the electron beam energies 1-8 GeV
  3. Positron yield from 9mm thick crystal is 26% greater than 18mm amorphous at 8 GeV
  4. Effective radiation lengths for crystal is compressed;

     $L_{eff} = 0.55 \times L_{rad}$ at 8 GeV, 0.62 at 4 GeV
  5. Enhancement factors; Good agreement with Baier and Strakhovenko
     - For a given number of accepted positrons, the energy deposited in a crystal is less than in an amorphous; ~40% smaller at 5 GeV

Summary (cont.)

- Need better simulation codes; Our data for W_c will become a set of inputs for improving calculations and simulations
- Diamond 5mm and Si 10,30,50 mm

1. Preliminary data showed large enhancement for diamond; ~20
2. Combinations with amorphous W; wait for analysis
3. More experiments for thicker diamond; ~10 mm will be available