Tungsten mono-crystalline target for a high-intensity positron source

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Motivation

- **High-intensity positron sources are required for future *linear colliders* and *B-factories*.**
- **Conventional methods using amorphous heavy metals limit to increase the intensity of primary electron beams due to the heat load on the target.**
- **New method using a *mono-crystalline target* for positron production is expected to be one of the bright schemes for high-intensity e^+ sources.**

Introduction

- **New method utilizing a crystal target was proposed by Chehab, *et al.* in 1989.**

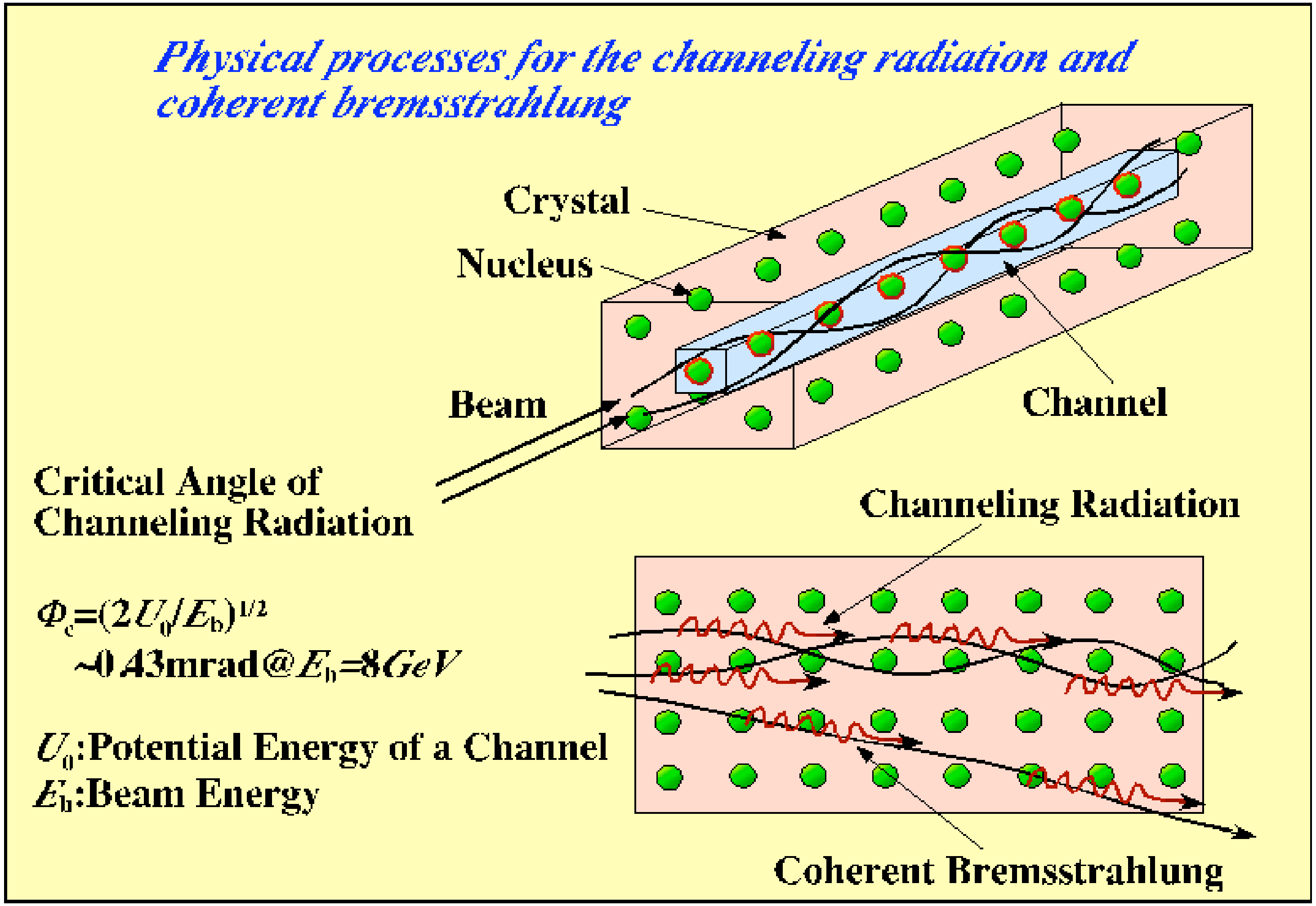
  (R. Chehab, *et al*., PAC'89, Chicago, IL, USA, Mar. 1989, p.283)

- **Yoshida, *et al*., demonstrated a clear enhancement of the *e+* yield in a tungsten crystal target using a 1.2-GeV electron beam of INS/Tokyo.**

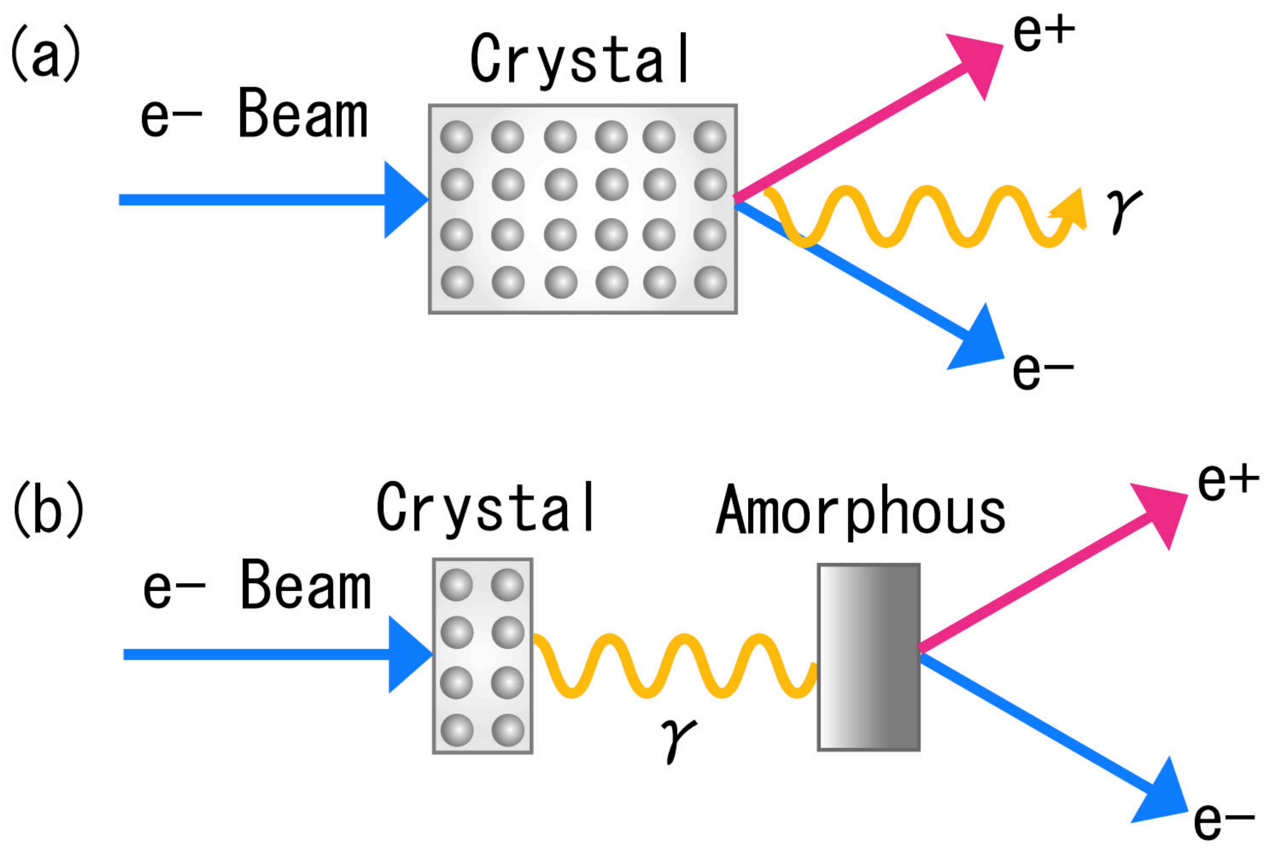
  (K. Yoshida, *et al*., Phys. Rev. Lett. 80, 1437, 1988)

- **However, any theoretical studies taking into account both processes of *Channeling Radiation (CR)* and *Coherent Bremsstrahlung (CB)* has not yet been established on the simulation.**
- **More experimental data are expected to clearly understand the physical interaction processes of the *CR* and *CB*.**

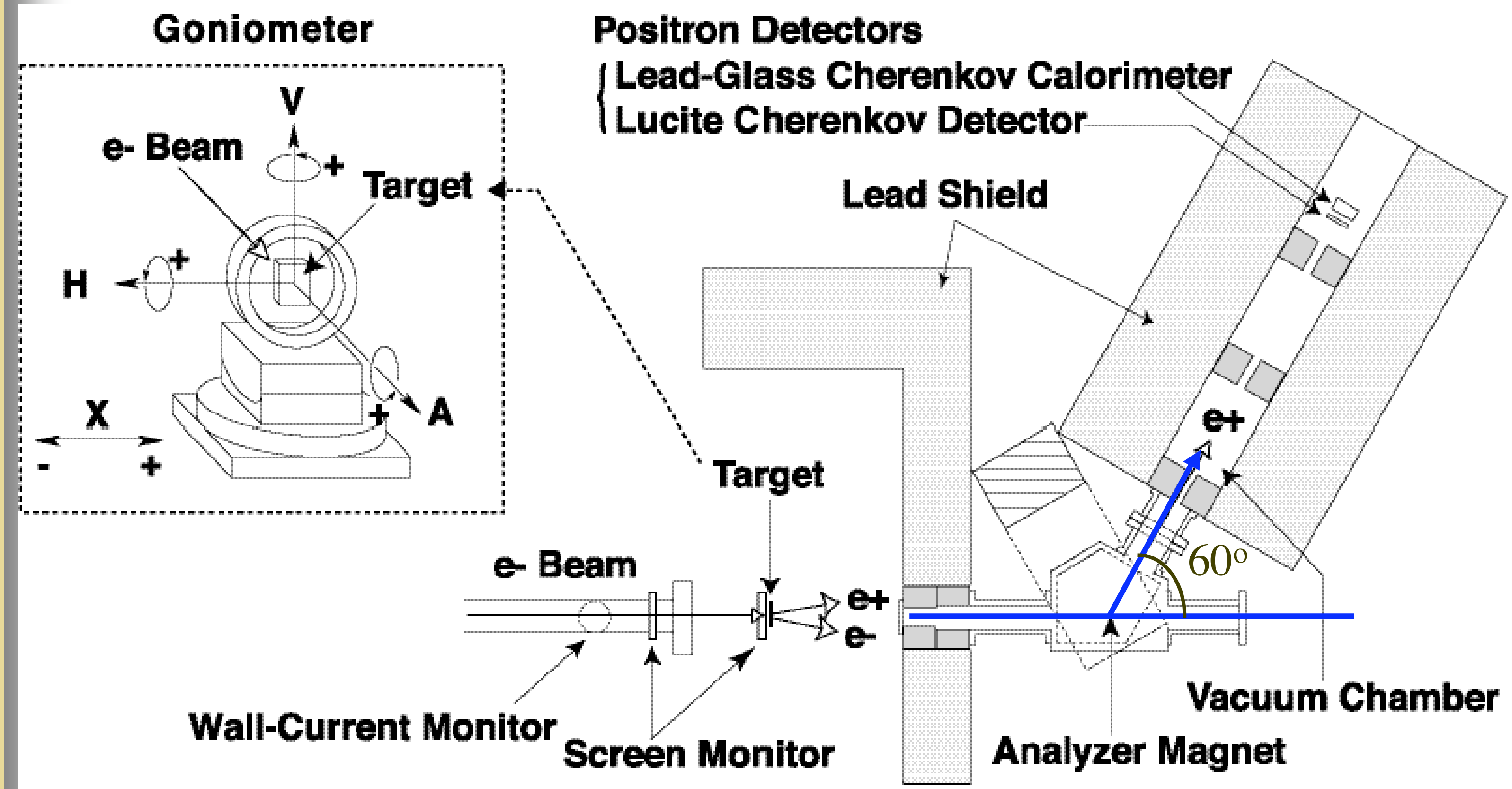
Channeling Radiation & Coherent Bremsstrahlung Processes



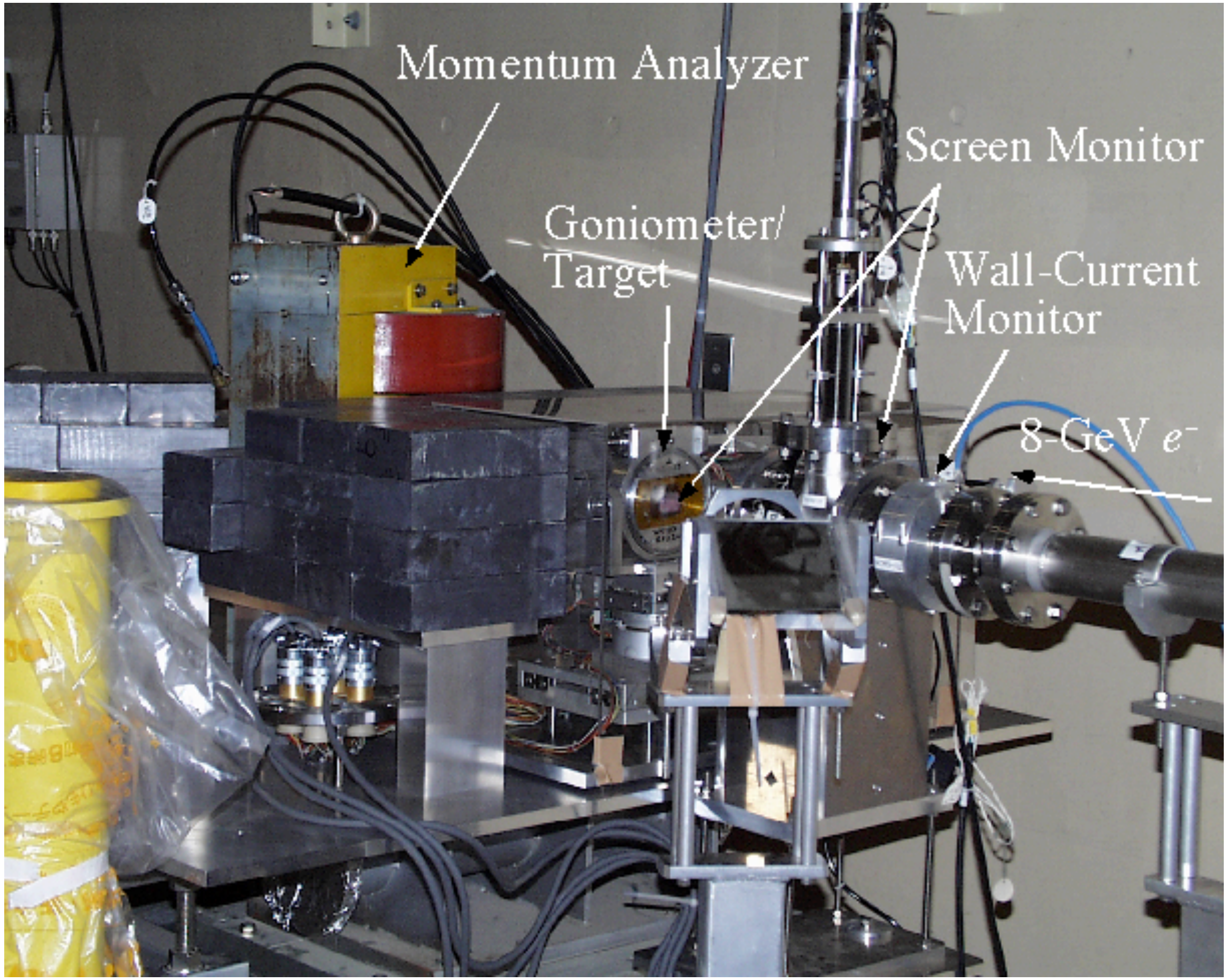
New Positron Production Schemes



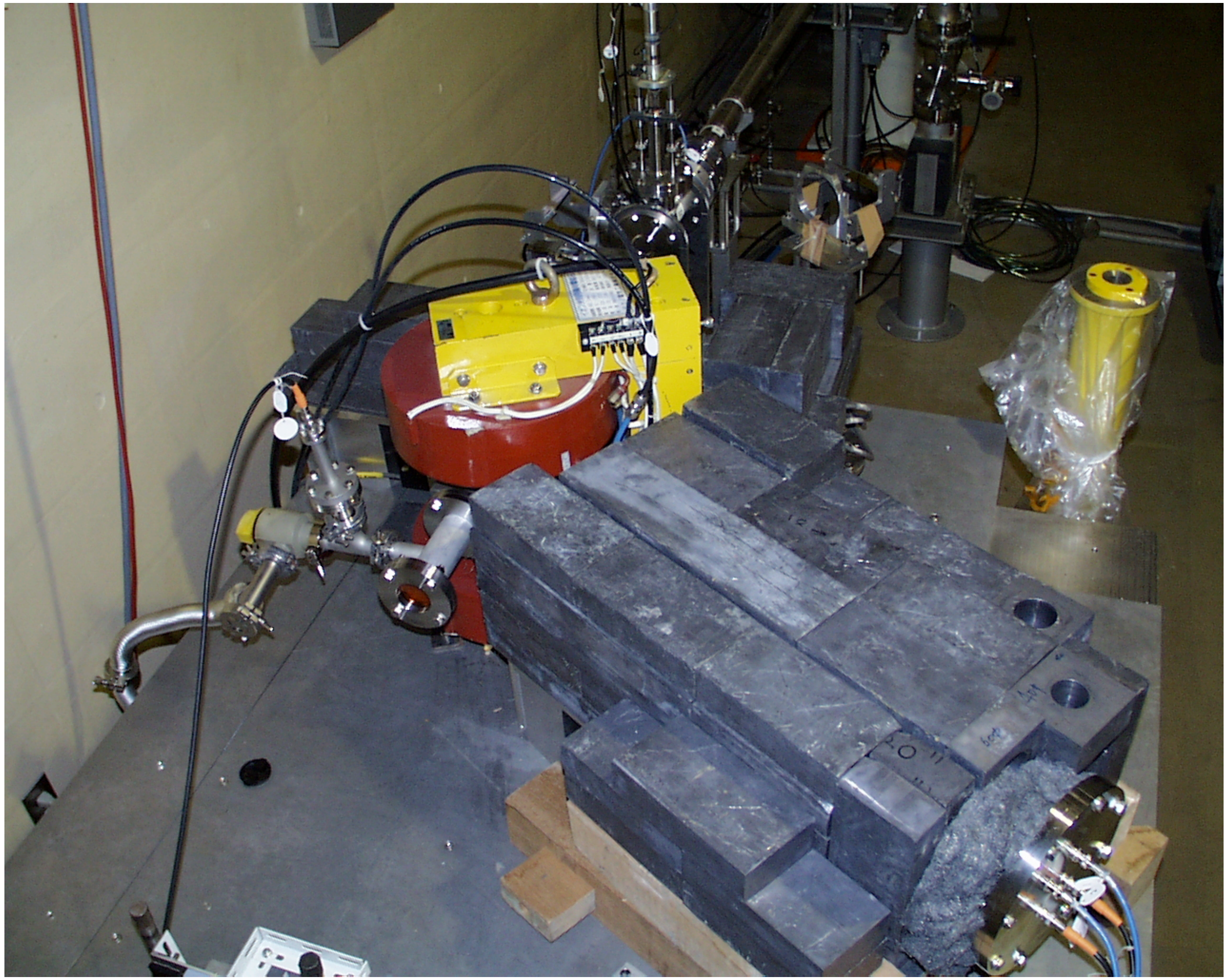
Experimental Setup



Linac Beam Line at the 3rd switch yard



Experimental Setup (cont'd):Positron spectrometer



Acceptance of the Positron Spectrometer

P_{e^+} (MeV/c)	Acceptance ($\Delta P \Delta \Omega$) ($10^{-4}\times$(MeV/c)$\cdot$sr)
5	1.08 $\pm$0.03
10	2.47 $\pm$0.07
15	3.80 $\pm$0.01
20	4.81 $\pm$0.12

- **The acceptance ($\Delta P \Delta \Omega$) was obtained by using the simulation code (GEANT3).**
- **Typical acceptance**

  Momentum:

  $\Delta P/P$=2.4% (FWHM)&

  Geometrical:

  $\Delta\Omega$=1msr

  at P_{e+}=20MeV/c.

Experimental Condition

Electron Beam*: *S-band single bunch

- **Beam Energy = 4 (8) GeV**
- **Angular Spread ~123(23) μrad (H), ~121(41) μrad (V)**
- **Transverse Beam Size 1 ~1.5mm (FWHM) in diameter**
- **Beam Charge = 0.2 nC/bunch**
- **Bunch Length (Single Bunch) ~10 ps (FWHM)**
- **Beam Repetition = 25(2)Hz**

Angular Spread of the Electron Beam at the Positron Target

- **$\Phi \sim 0.2(0.1)$ mrad < Φc (due to multiple scattering by a vacuum window(100μm-thick SUS))**

Critical Angle for the Channeling Condition at the Positron Target

- **$\Phi c \sim 0.61(0.43)$ mrad @4 and 8 GeV (Linhard Angle)**

Experimental Condition (cont.)

***Positron-Production Targets*:**

- **Crystal Tungsten Target : 2.2, 5.3 and 9mm thickness**
- **Amorphous Tungsten Target : 2-28mm thick (for the e^+ production yield calibration)**
- **Amorphous Tungsten Target: 3-18mm (3mm step) thickness (for the purpose of hybrid targets)**

Detected Momentum Range

- **5 MeV/c $\leq Pe^+ \leq$ 20 MeV/c**

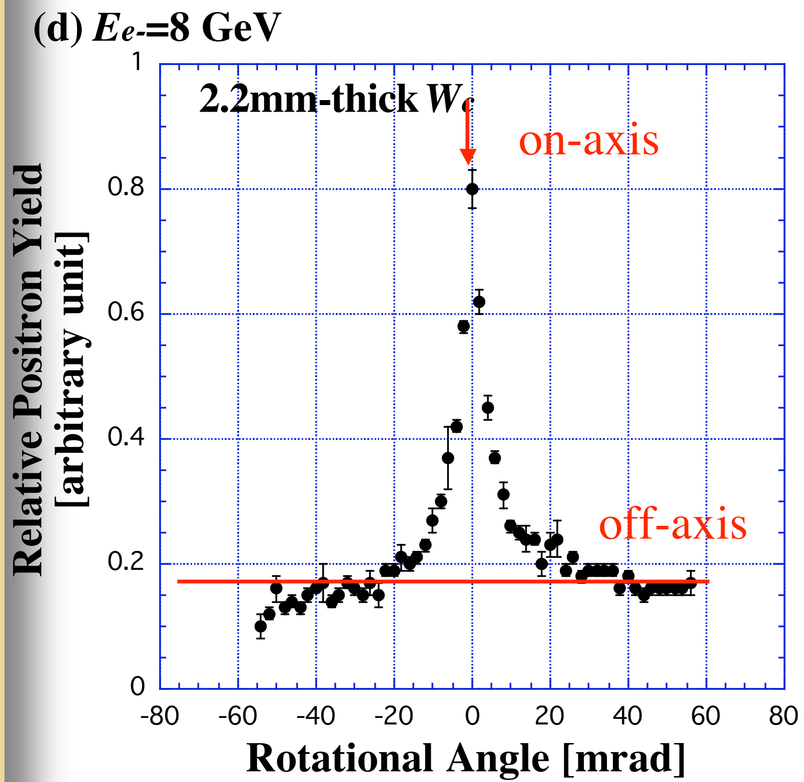
Positron Detectors

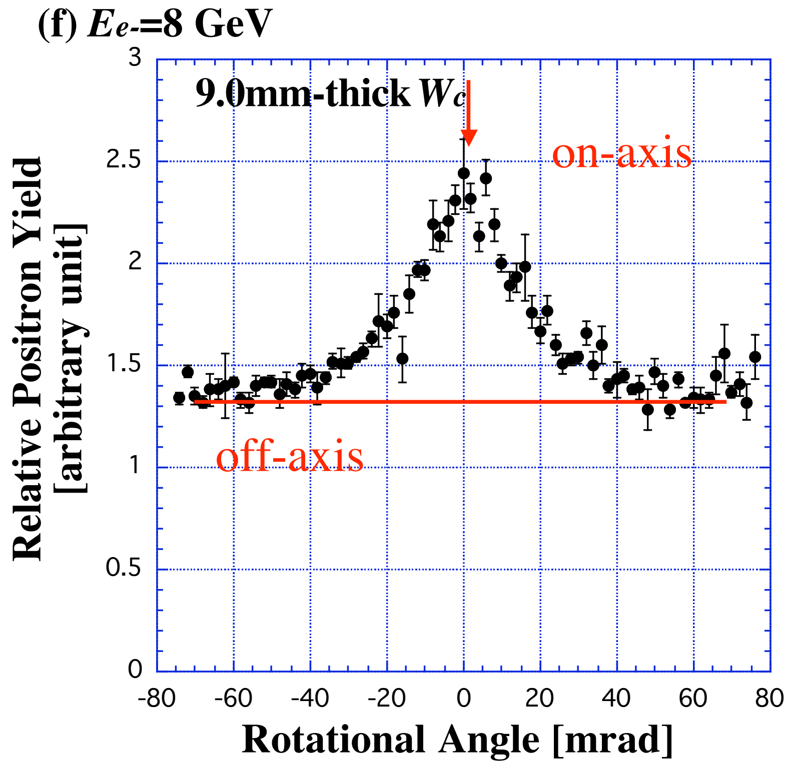
- ***Lead-Glass Calorimeter:Measurement of total energy of e+***
- ***Acrylic Cherenkov Counter:Measurement of number of e+***

Beam Monitors

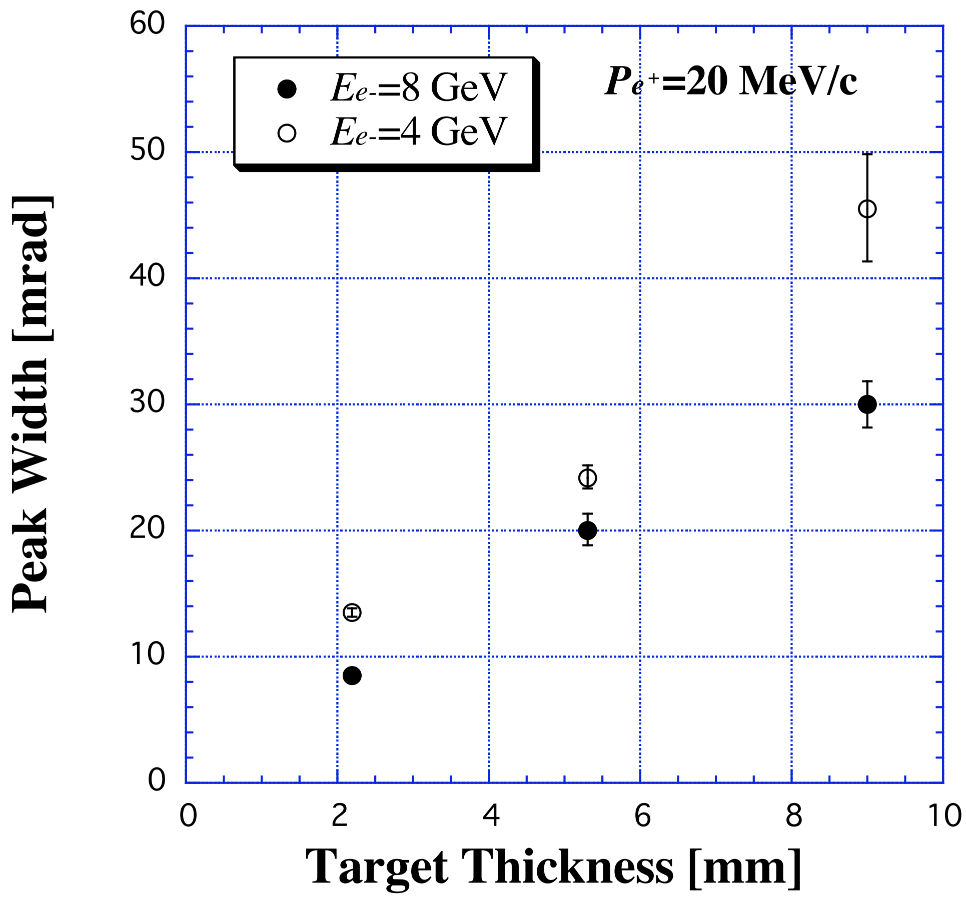
- ***Wall-current monitor* for the electron beam-charge measurement**
- ***Screen monitor* for the beam-profile measurement**

Experimental Results: Rocking Curves (Crystal Axis <111>) at Ee-=4 and 8 GeV (Pe+=20MeV/c)

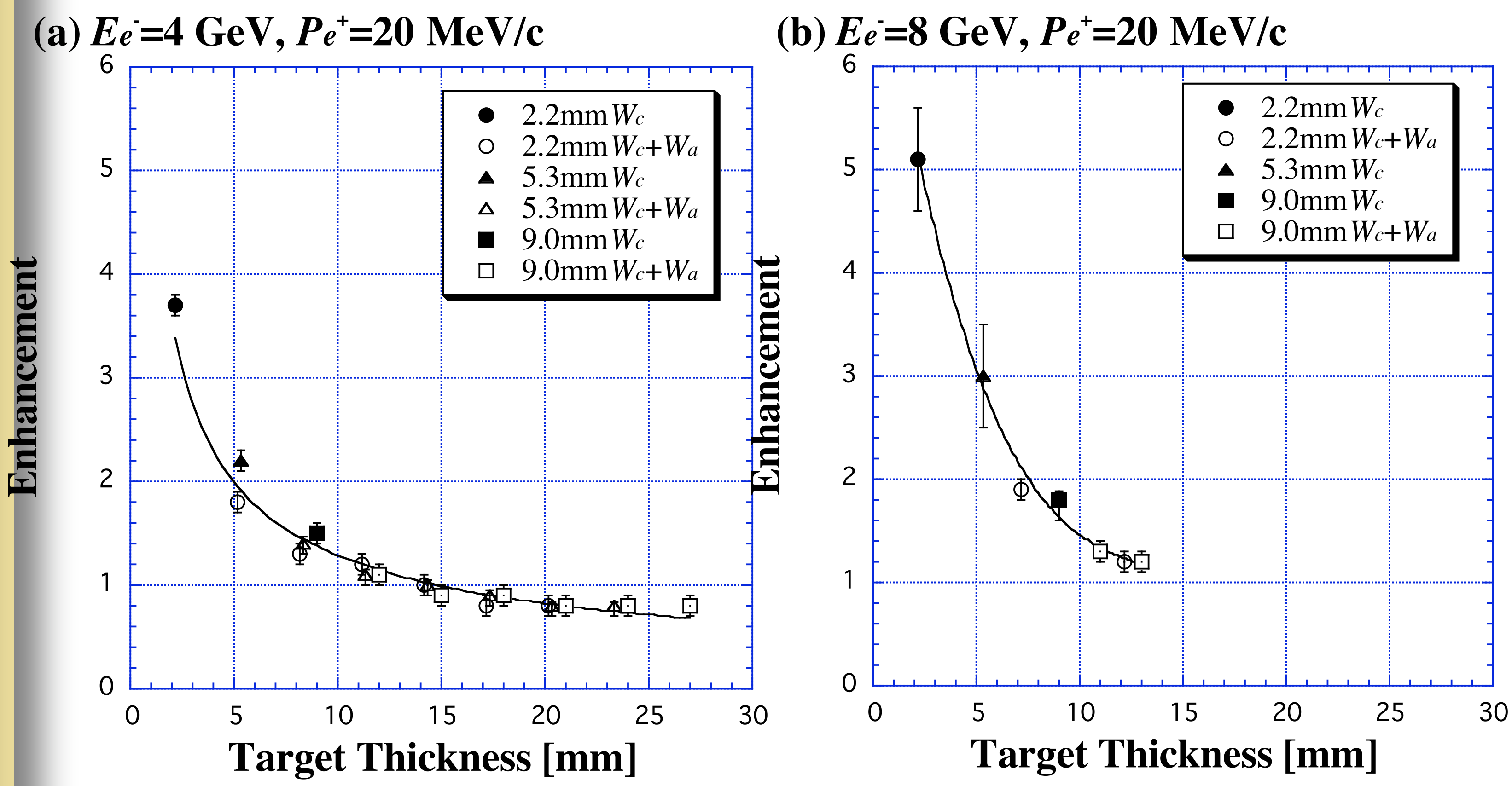




Experimental Results: Variations in the width of the rocking-curve peak for Ee-=4 and 8 GeV (Pe+=20MeV/c)



Experimental Results: Variations in the enhancement ($N_{e+@peak}$/ $N_{e+@base}$) of the e+ yield at Ee-=4 and 8 GeV (Pe+=20MeV/c)

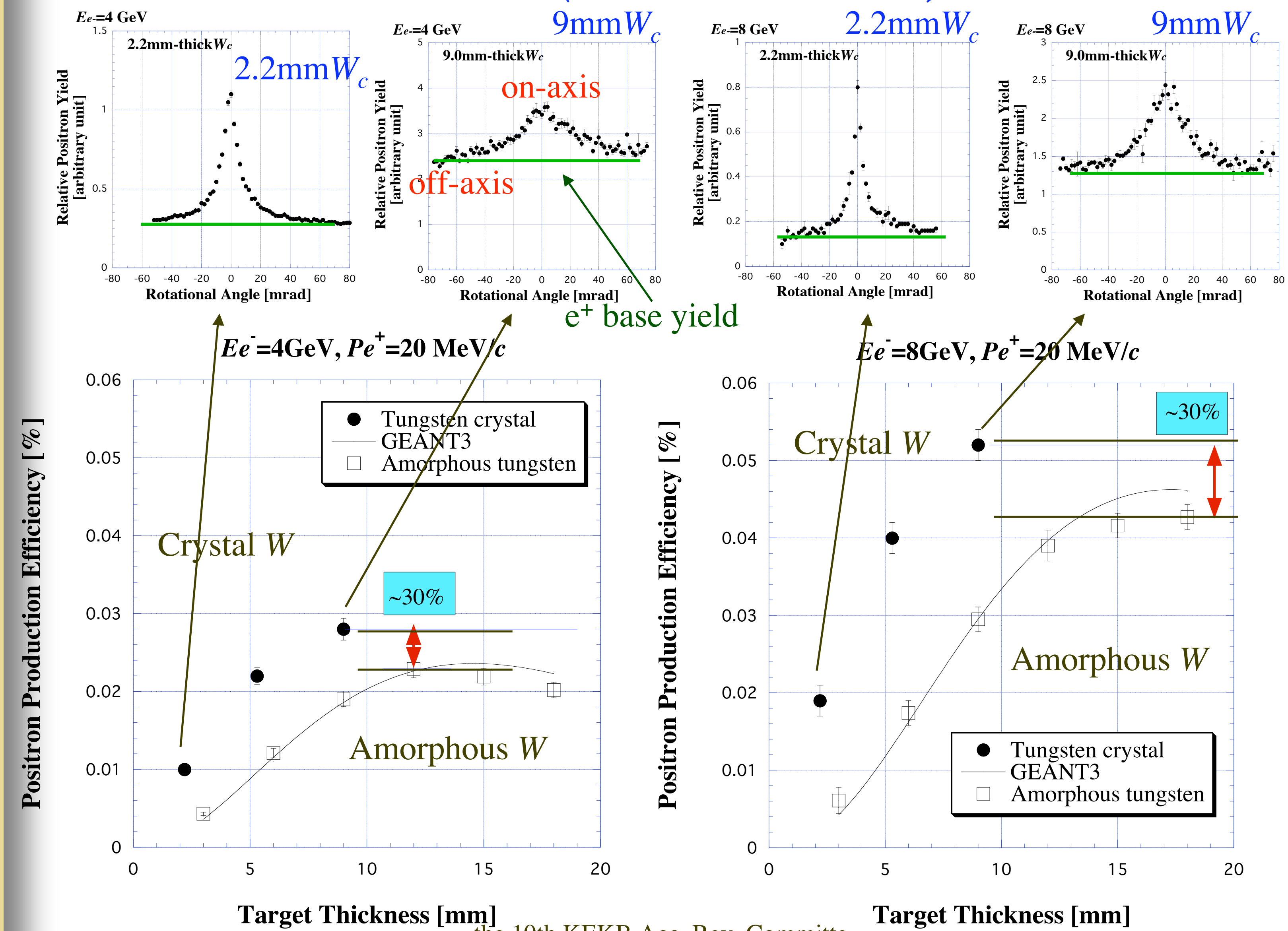


Experimental Results: Momentum dependence of the positron-yield enhancement

Table 2
Momentum dependence of the positron-yield enhancement for the crystal targets.
() are the simulation results by Baier and Strakhovenko [13]

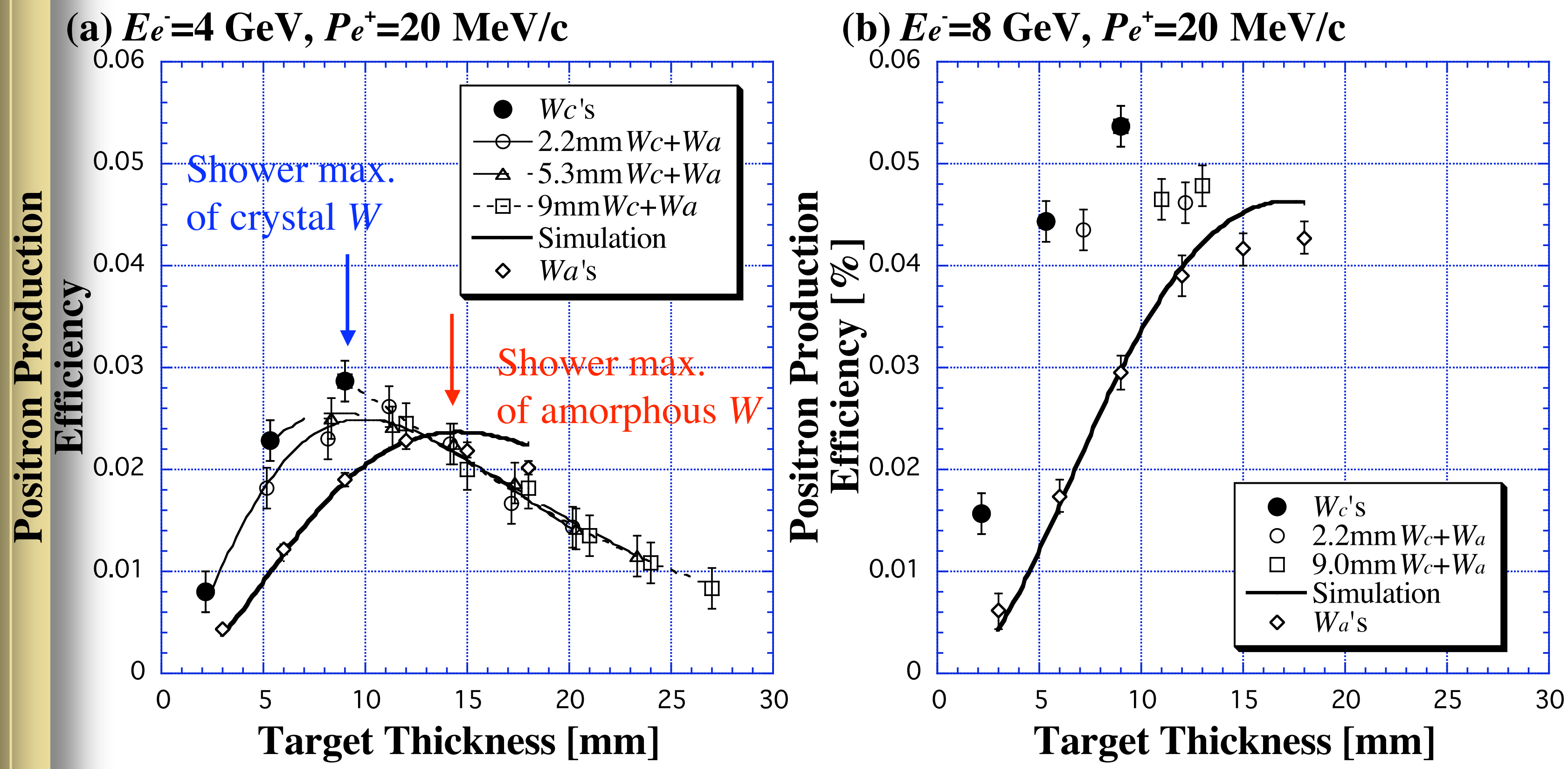
P_{e^+}	E_{e^-}=4 GeV			E_{e^-}=8 GeV		
(MeV/c)	2.2mm W_c	5.3mm W_c	9.0mm W_c	2.2mm W_c	5.3mm W_c	9.0mm W_c
5	3.3 ± 0.1	2.2 ± 0.1	1.5 ± 0.2	5.0 ± 1.5	2.9 ± 0.5	2.1 ± 0.3
10	3.6 ± 0.3	2.3 ± 0.1	1.5 ± 0.2	6.5 ± 0.6	3.4 ± 0.7	2.3 ± 0.4
				(6.0 ± 0.5)	(3.2 ± 0.3)	(2.1 ± 0.2)
15	3.5 ± 0.1	2.2 ± 0.1	1.7 ± 0.3	6.2 ± 0.8	3.2 ± 0.5	2.0 ± 0.2
				(5.5 ± 0.3)	(3.2 ± 0.2)	(2.0 ± 0.1)
20	3.7 ± 0.1	2.2 ± 0.1	1.5 ± 0.1	5.1 ± 0.5	3.0 ± 0.5	1.8 ± 0.2
				(5.4 ± 0.2)	(2.9 ± 0.1)	(1.8 ± 0.1)

e+ production efficiencies for the crystal tungsten at Ee-=4 and 8 GeV (Pe+=20MeV/c)



Suwada, *et al.*, *Phys.Rev.*E 67, 016502 (2003)

Experimental Results: e+ production efficiencies for the crystal and combined targets at Ee-=4 and 8 GeV (Pe+=20MeV/c)



Conclusions

♠ *Rocking curves*

- *The obtained widths of the rocking-curve peak is much larger than the critical angle, and broaden with the thickness of the crystal target.*
- *The broad widths of the rocking curves indicate that the CB process may be predominant over CR process in this energy region.*
- *The increase of the peak width depending on the target thickness may come from the multiple scattering of the incident electrons in the target.*

♠ *Enhancement of the e^+ yield @Pe+=20MeV/c*

- **4GeV *En*=3.7 ±0.1 (2.2mm), 2.2 ±0.1 (5.3mm), 1.5 ±0.1 (9mm)**
- **8GeV *En*=5.1 ±0.5 (2.2mm), 3.0 ±0.5 (5.3 mm), 1.8 ±0.2 (9mm)**

♠ *Positron production efficiency for the crystal targets*

- *The absolute e+ yields were enhanced by ~26% with Pe+=20MeV/c by 15 and 18% on the average with the momentum range of 5-20MeV/c at Ee-=4 and 8GeV, respectively, compared with the maximum e+ yield obtained for the amorphous target.*
- *We have a new plan to install a tungsten mono-crystalline target at the present e+ source in this summer.*