Development of Start-to-End Simulation for ILC positron sources

KEK M. Fukuda

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- Purpose of Development of Start-to-End Simulation for ILC positron sources
- Simulation test on the undulator scheme using Geant4
- Comparison of simulation results

The purpose of development of simulation for ILC positron source

- I will develop start-to-end simulation codes for ILC positron source.
  - Positron generation of target: Geant4
  - Target to Capture section: Geant4 or GPT
  - Booster section to DR: SAD
- **The purpose is to compare the yield calculation of positron generation for both undulator scheme and e-driven scheme under the same condition.**
- I am developing the simulation program from the positron generation to the end of the capture section.
  - Code: Geant4.10
  - The program is based on the example program of B4.

Simulation of a positron source for undulator method

I am making the simulation code for a positron source by using Geant4.10.
The tracking of positrons up to the exit of Capture section (125MeV) can be simulated now.

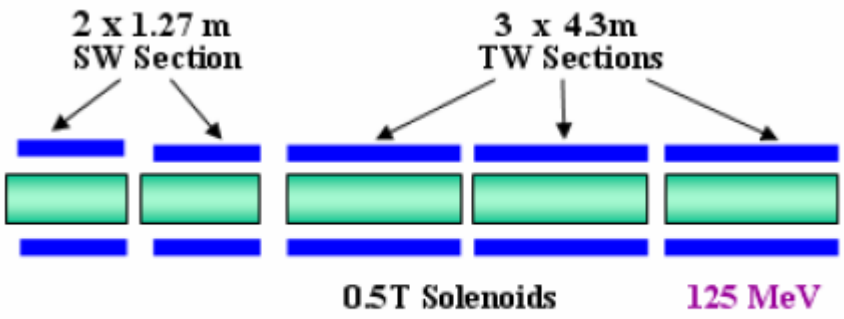

Figure 1. Schematic layout of the capture region.

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The tracking of positrons after the capture section is simulated by T. Okugi.

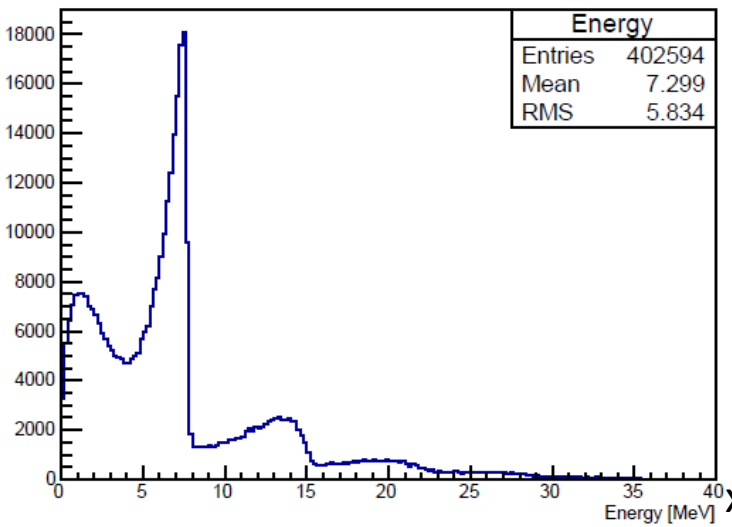
Positron generation at a target --- Capture section (125MeV): calculated by M. Fukuda
Tracking of positrons after Capture section: T. Okugi

Positron generation

Gamma-rays data from Undulators was calculated by CAIN (Yokoya's calculation)
Number of Gamma-rays: 4.03e6 (4,025,930).
There are generated from 10,000 electrons with the energy of 125GeV.

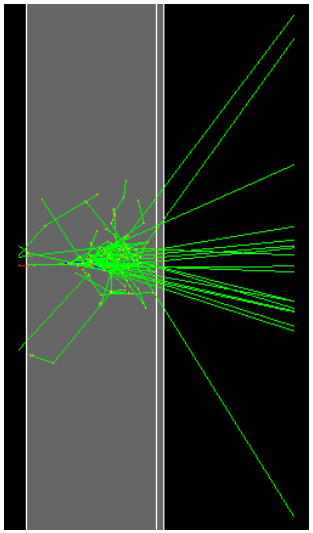
Target: **Ti6Al4V, thickness 7mm**
Number of generated positrons: 4.43e4

Gamma-rays from Undulator

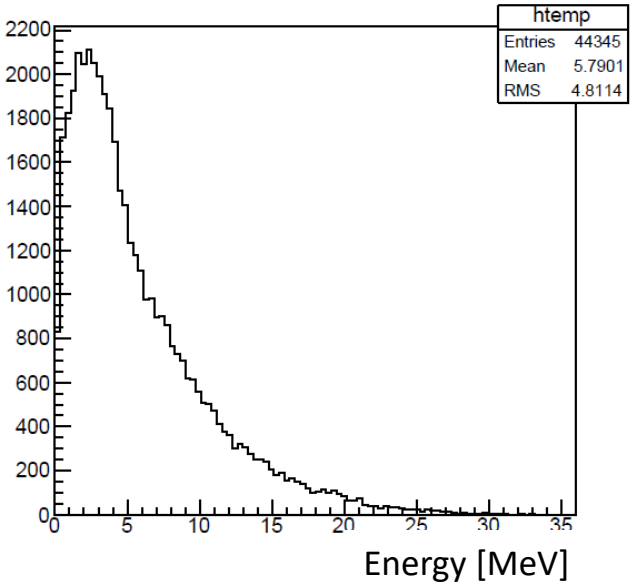


x10

Ti6Al4V 7mm



Generated positrons



Magnetic field of QWT and Solenoid

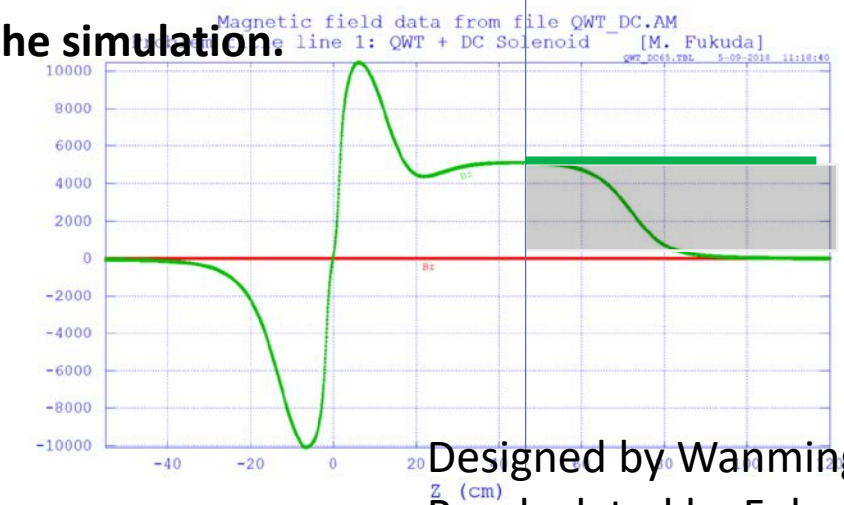
The magnetic field data was calculated by POISSON.

This 2D map data of magnetic field is used in the simulation.

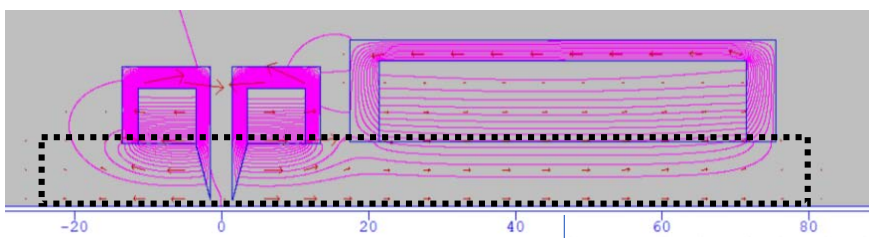
QWT (Peak 1.04T) + 0.5T (capture section)

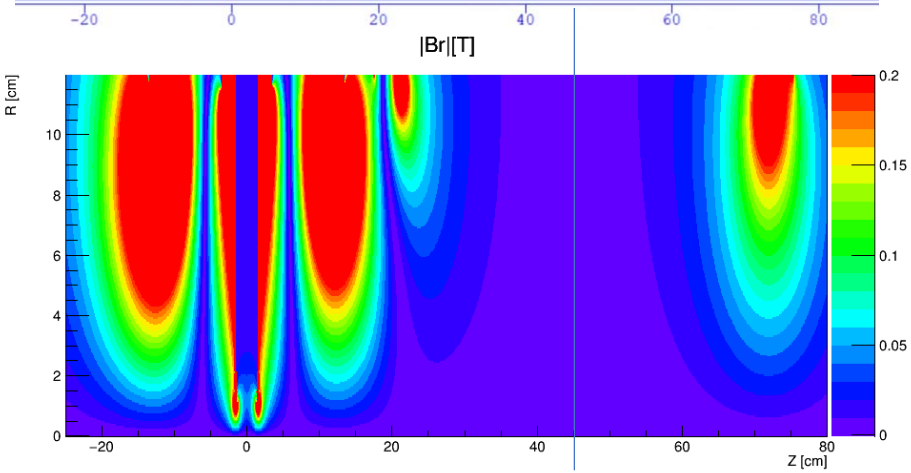
After z = 444.5mm, Bz = const. (~0.51T), Br =0

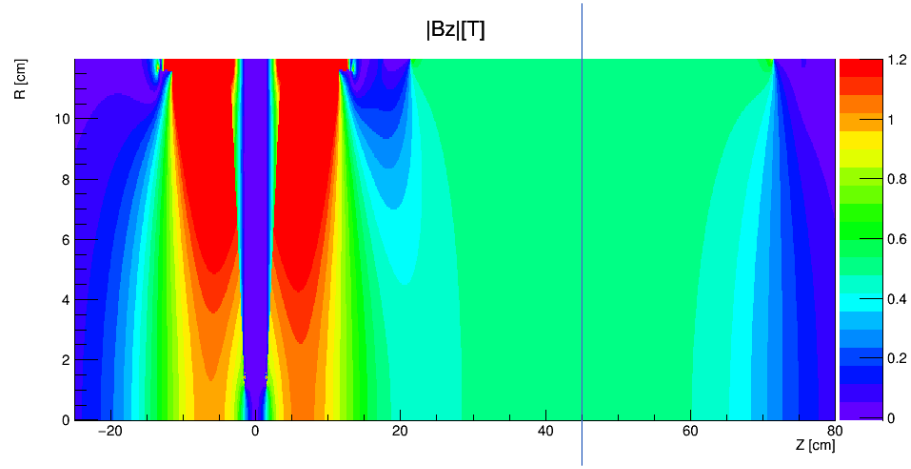
Bz = const. Br=0



Designed by Wanming Liu
Recalculated by Fukuda



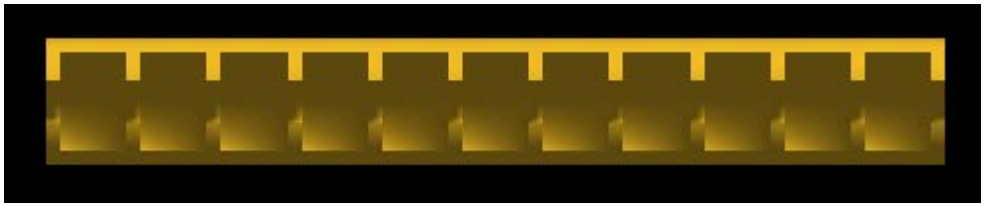




Accelerating electric field of standing wave tube

I consider only the accelerating electric field Ez.

1.27m (11cells)



Aperture(2a): 60mm

Ez = E0*2*sin(omegaspace*(z-zfrontRF)*cos(omegatime*t+Ephase)

omegaspace = k = 2π/λ

omegatime = ω = 2πf = 2πc/λ

λ=230.60958mm (L-band)

Eacc: 15.2MV/m

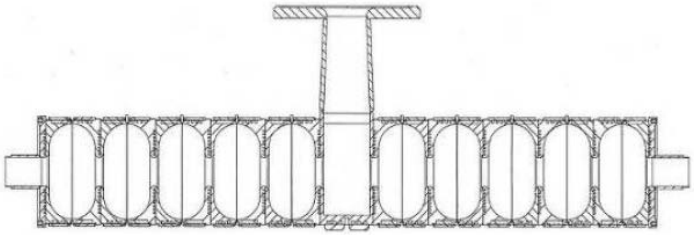


Figure3: 11–cell SW structure.

Table 1: Parameters of SW stricture.

Structure Type	Simple π Mode
Cell Number	11
Aperture 2a	60 mm
Q	29700
Shunt impedance r	34.3 MΩ/m
E_0 (8.6 MW input)	15.2 MV/m

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Accelerating electric field of traveling wave tube

Aperture(2a): 46mm

4.3m (50cell)

I consider only the accelerating electric field Ez.

Ez = E0*std::sin(omegaspace*(z-zfrontRF) - omegatime*t -Ephase)

omegaspace = k = $2\pi/\lambda$

omegatime = $\omega = 2\pi f = 2\pi c/\lambda$

λ=230.60958mm (L-band)

Eacc: 7.2MV/m

Table 2. Parameters of TW structure

Structure Type	TW $3\pi/4$ Mode
Cell Number	50
Aperture 2a	46 mm
Attenuation τ	0.98
Q	24842 - 21676
Group velocity Vg/c	0.62% – 0.14%
Shunt impedance r	48.60 – 39.45 MΩ/m
Filling time T_f	5.3 μs
Power Dissipation	8.2 kW/m
E_0 (8.6 MW input)	8.0 MV/m

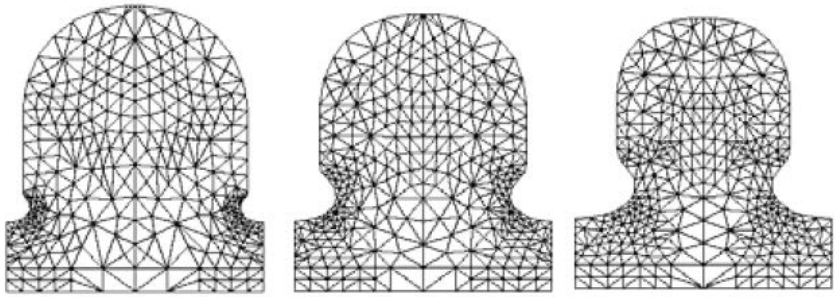

Figure 4. Profiles of the first, middle and last cell for 4.3m $3\pi/4$ Mode TW structures,

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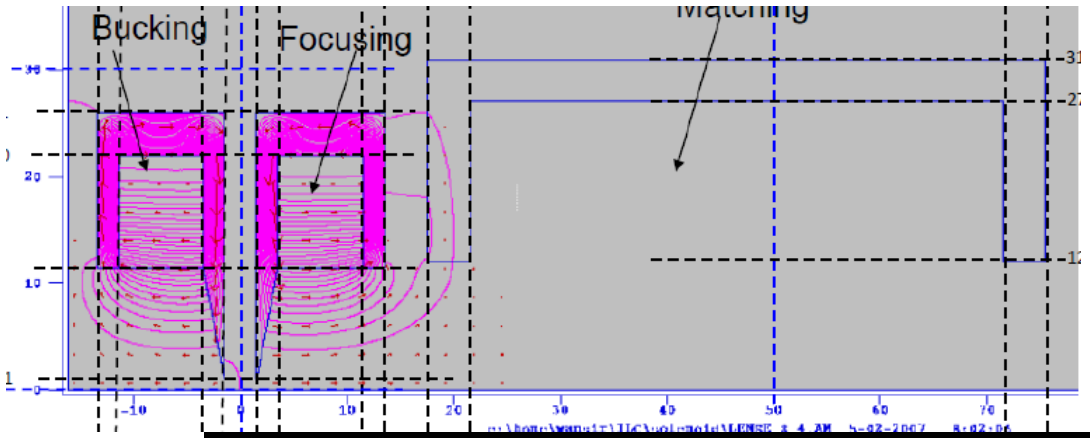
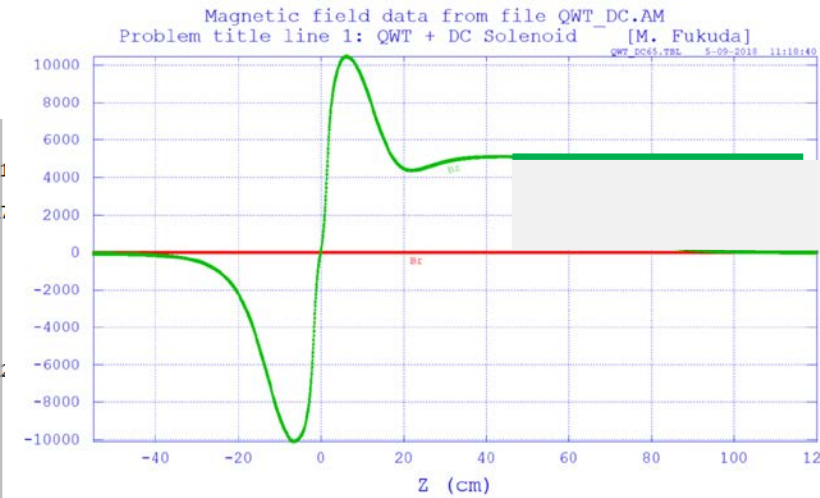
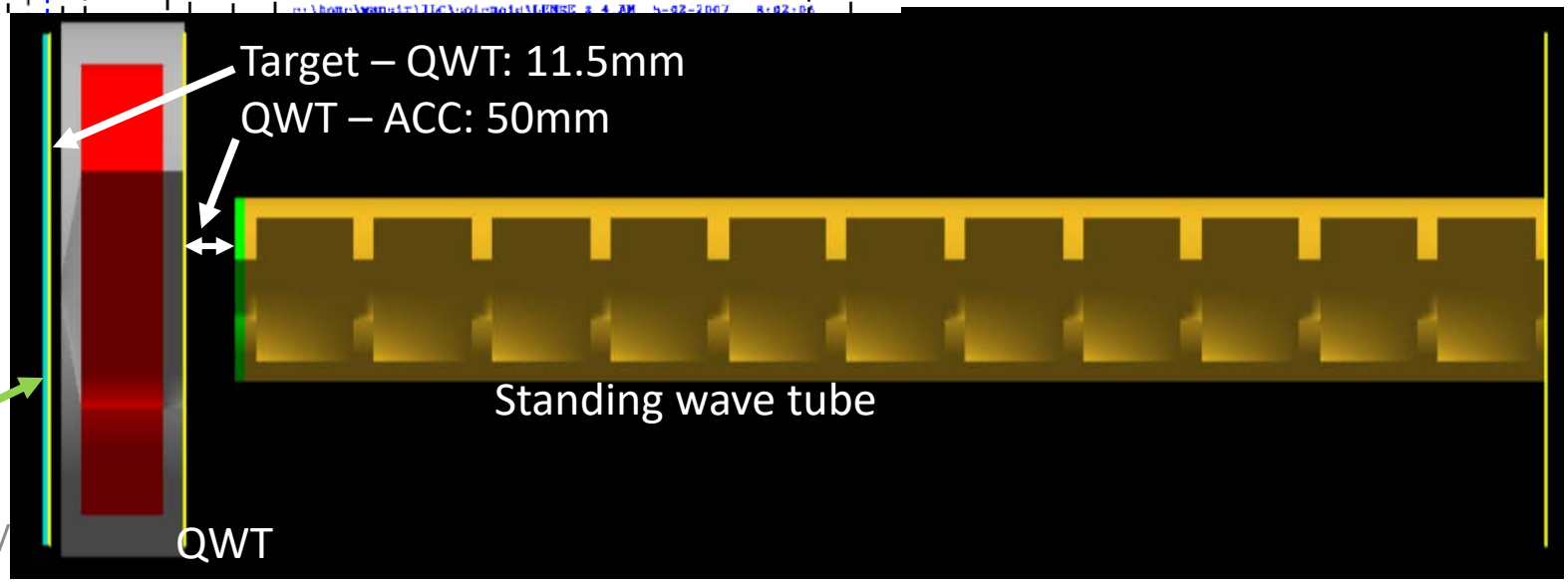
Placement of the QWT and an accelerator



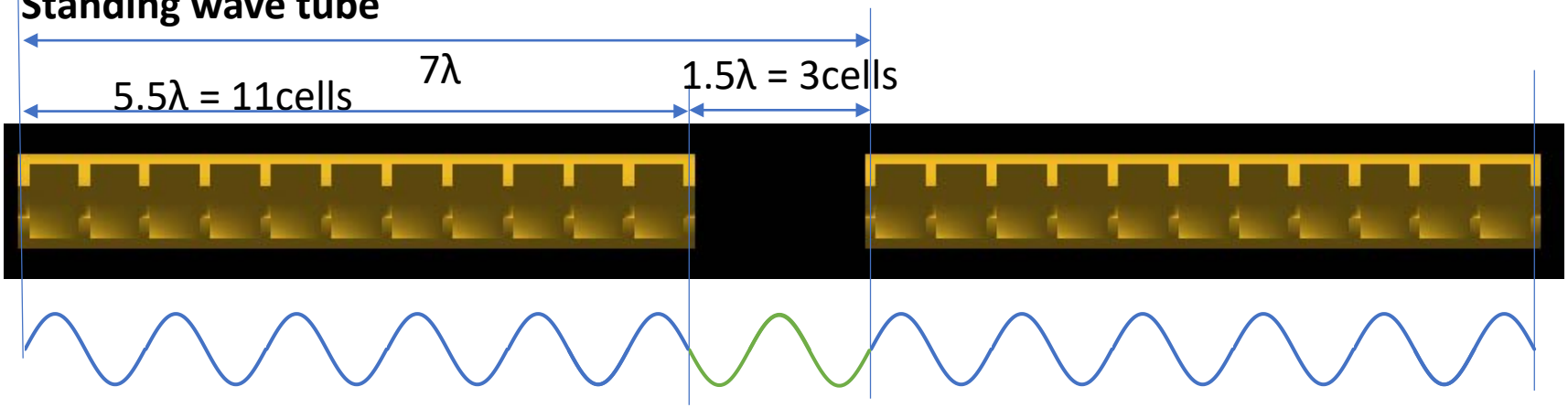




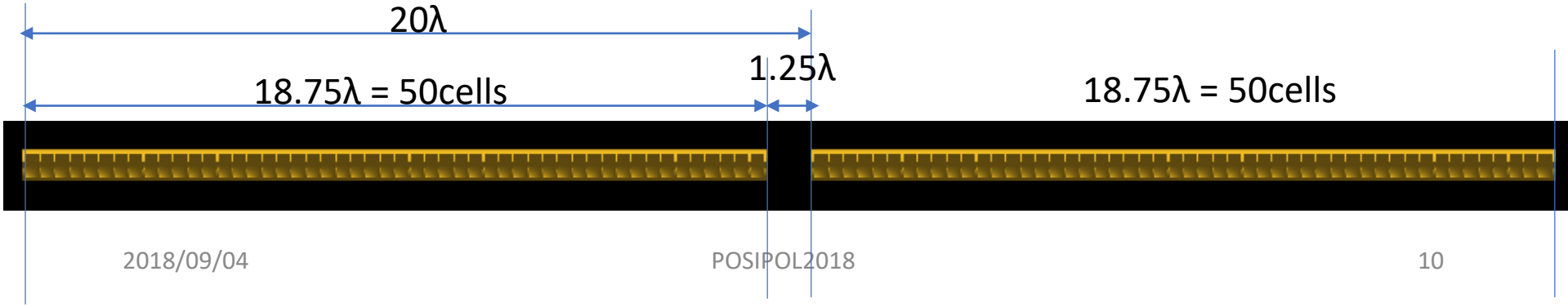
Arrangement of acceleration tube

I adjusted the space between the accelerating tubes so that the accelerating tubes would have the same acceleration phase.
The distance between accelerating tubes is an integral multiple of the wavelength.

Standing wave tube



Traveling wave tube:



Parameters of the simulation up to the capture section for undulator scheme

Input ：Gamma-rays from Undulators calculated by CAIN (Yokoya's calculation)
Number of Gamma-rays is 4,025,930 which are generated from 10000 electrons with 125GeV.

Target：**Ti6Al4V, 7mm**

OMD: **QWT (Peak 1.04T) + 0.5T (capture section)**
The magnetic filed was calculated by POISSON.

Accelerating tube : SWx2 + TWx3

Standing wave tube: Eacc: 15.2MV/m, L-band (1.3GHz) 11cell (1.268m)

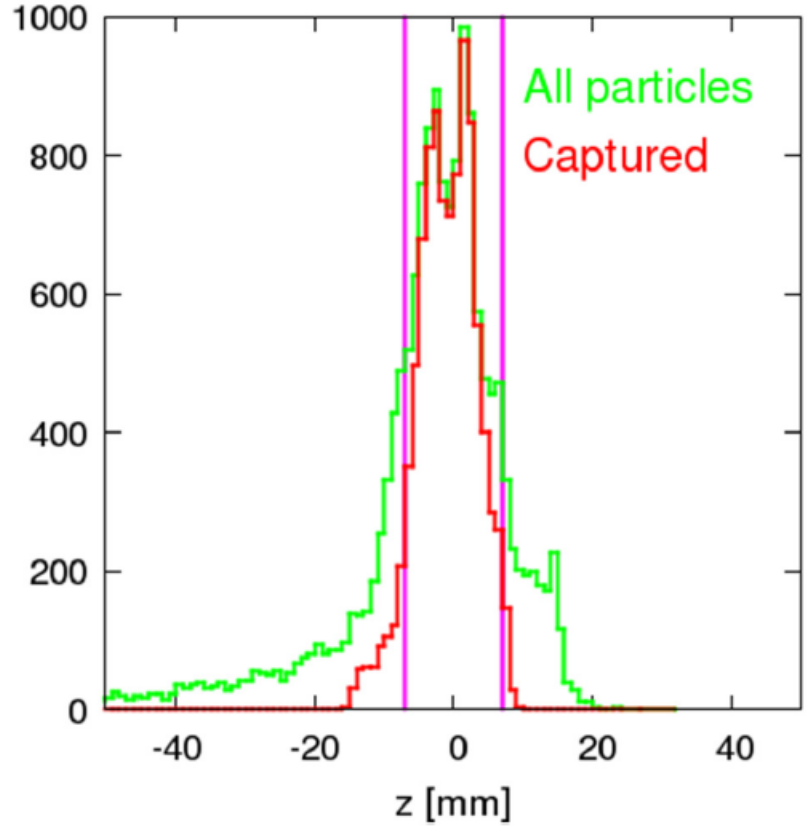
Traveling wave tube: Eacc: 7.2MV/m, L-band (1.3GHz) 50cell (4.324m)

→Positrons are accelerated to about 125MeV.

Phase scan of accelerators

The phase of the accelerator was optimized so that the number of positrons within +/- 7 mm in the longitudinal position distribution was maximized.

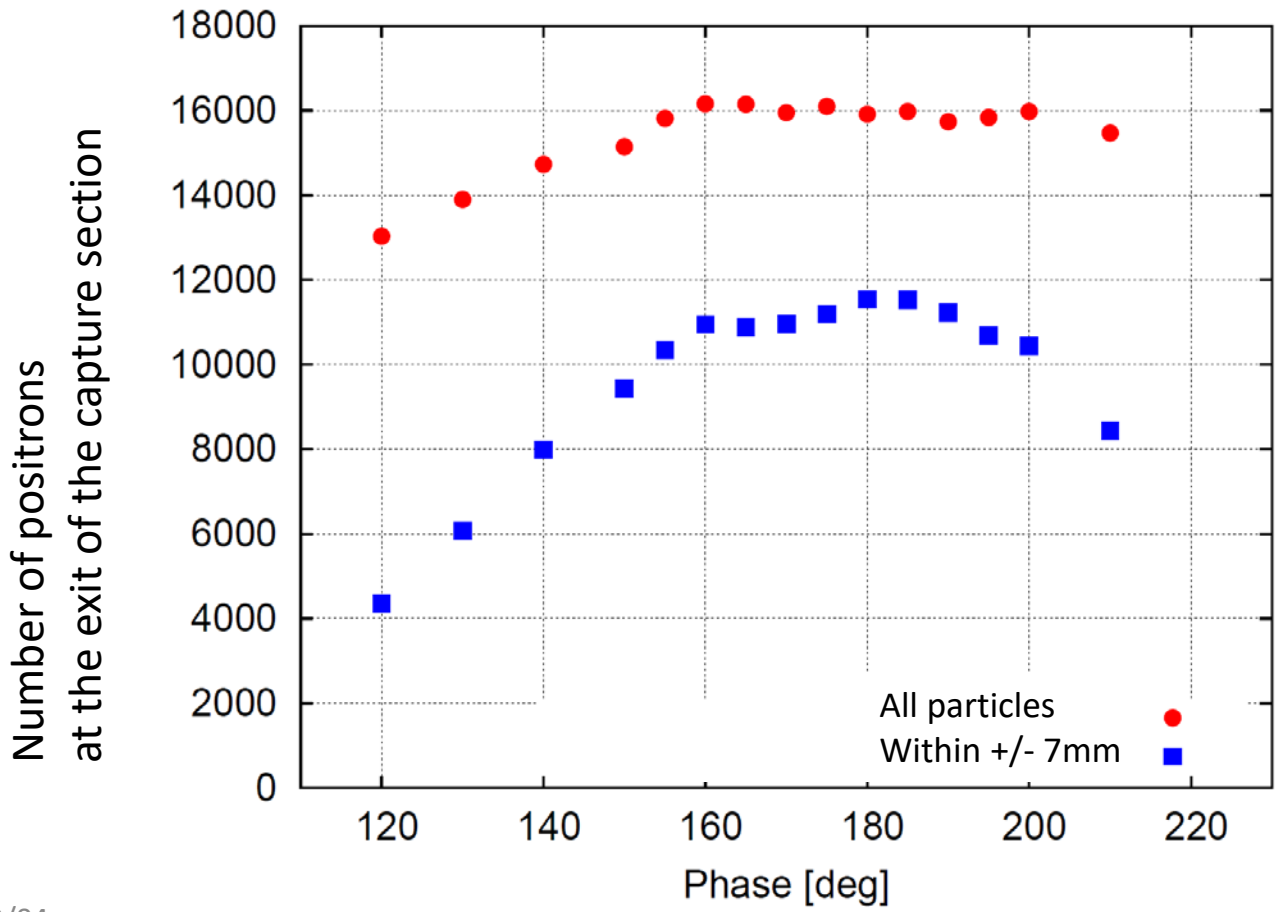
Positrons within +/-7mm in the longitudinal position distribution are captured in DR.



The phases of all the accelerating tubes were simultaneously moved.

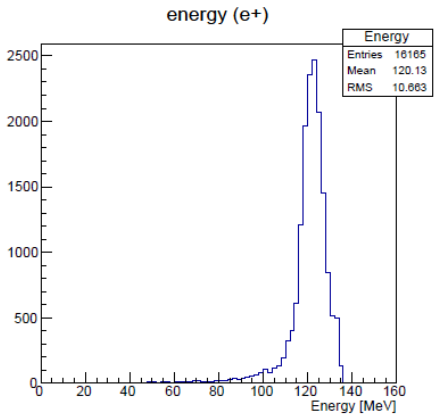
Analyzed by T. Okugi

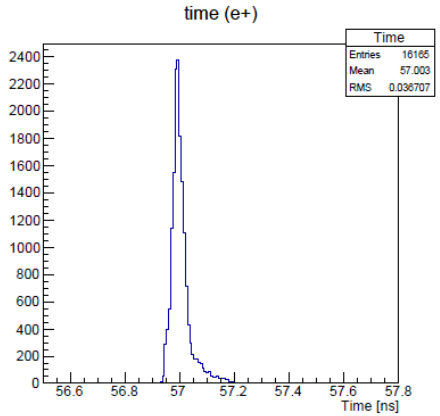
Number of positrons after capture section (125MeV)

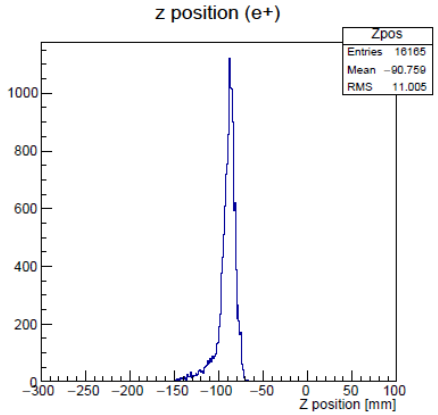


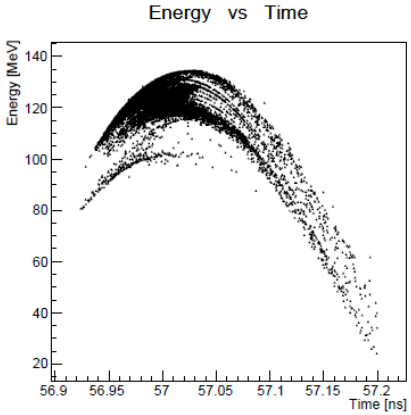
Energy, z position and time distribution of positrons

Phase 160deg

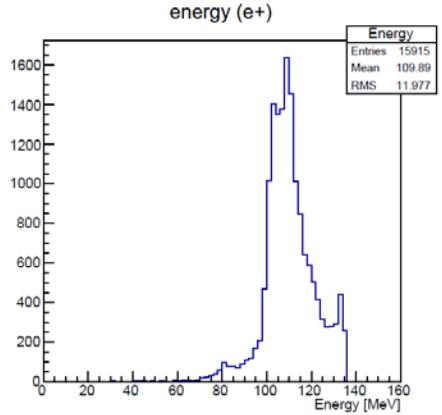


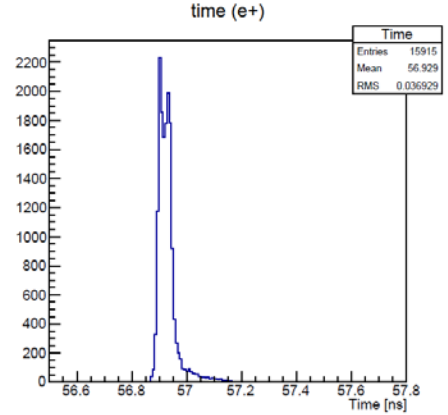


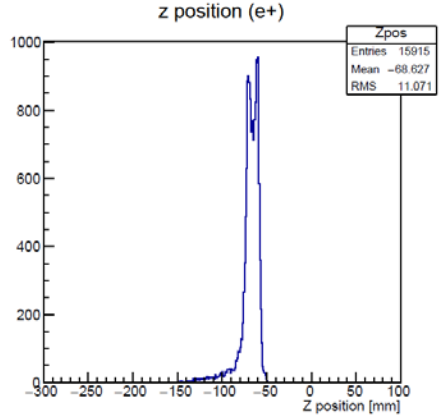


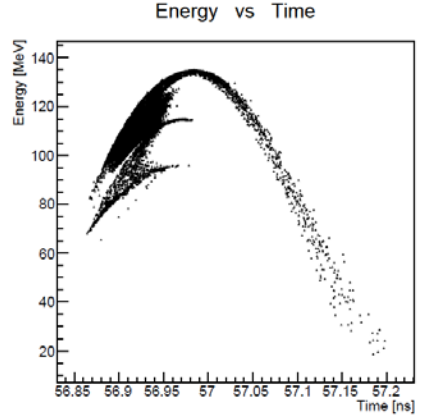


Phase 180deg









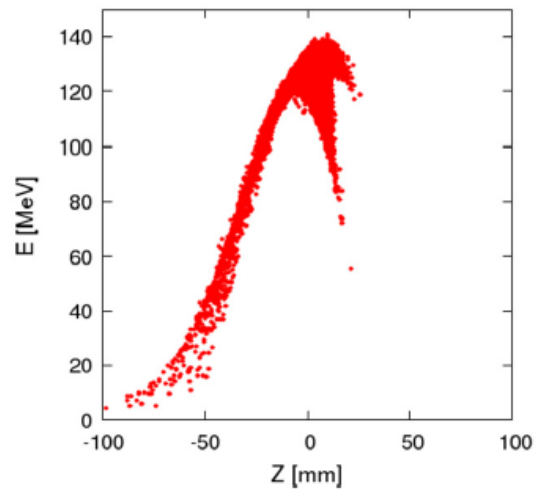
Tracking Simulations

simulated by Andriy Ushakov

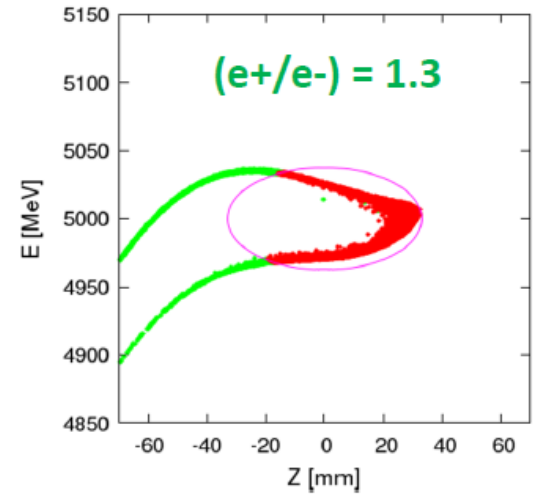
Used parameters are:

**126.5 GeV e- beam*
** 231 m undulator with K = 0.85*
** 401 m distance between the middle of undulator and the target*
** 7 mm target thickness (Ti6Al4V)*
** QWT with 1.04 T field solenoid downstream the target*
** Deceleation E-field downstream QWT*

Positron profile after 125MeV NC linac



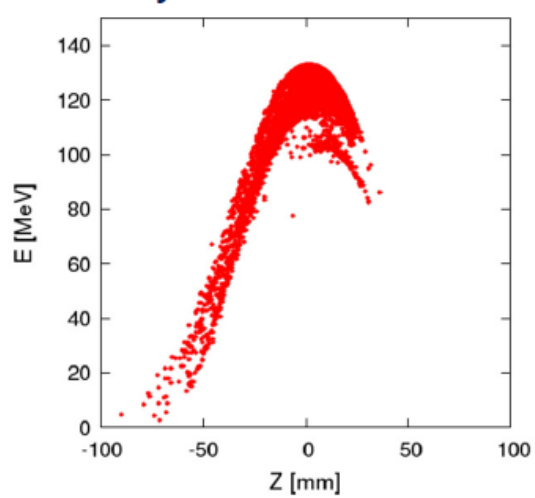
Transported to EC end



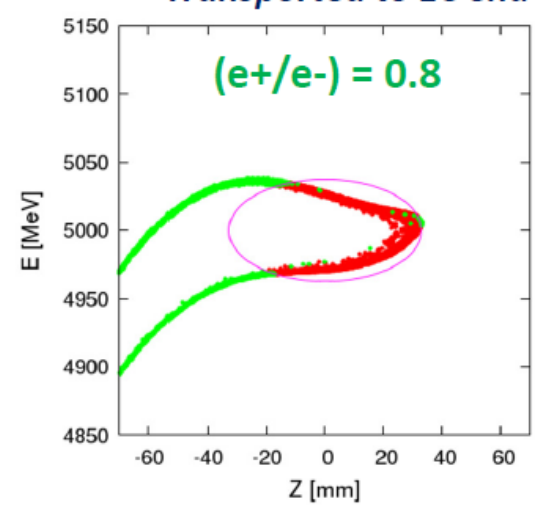
simulated by M. Fukuda

Target: Ti alloy (Ti-6AL-4V), 7mm
QWT: 1.04T
ACC SOL: 0.5T
ACC SWx2: Eacc 15.2MV/m
ACC TWx3: Eacc 7.2MV/m

Positron profile after 125MeV NC linac

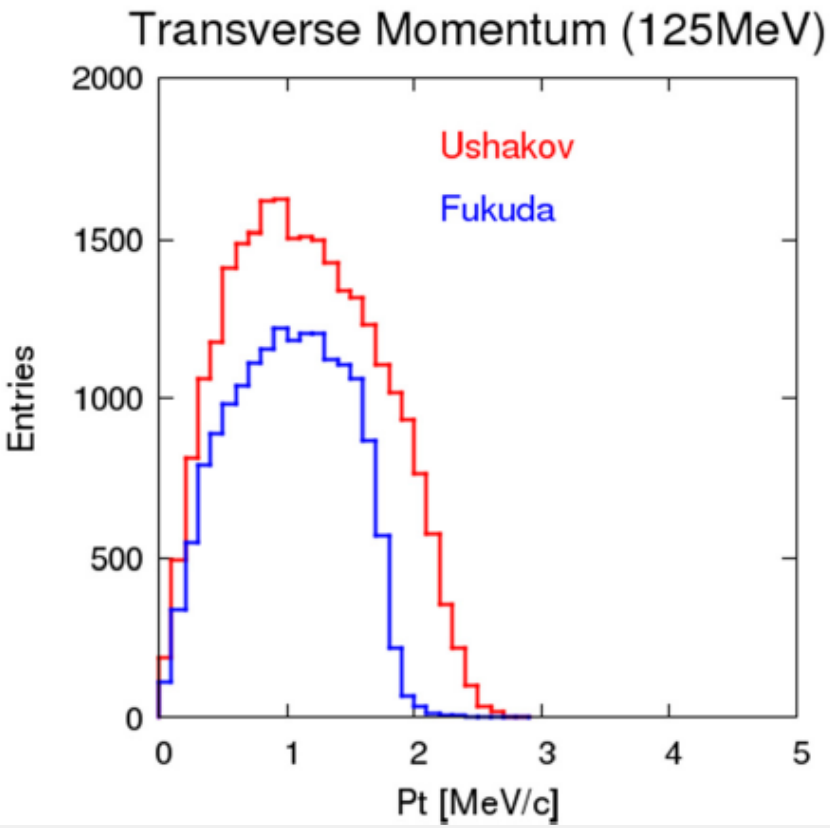


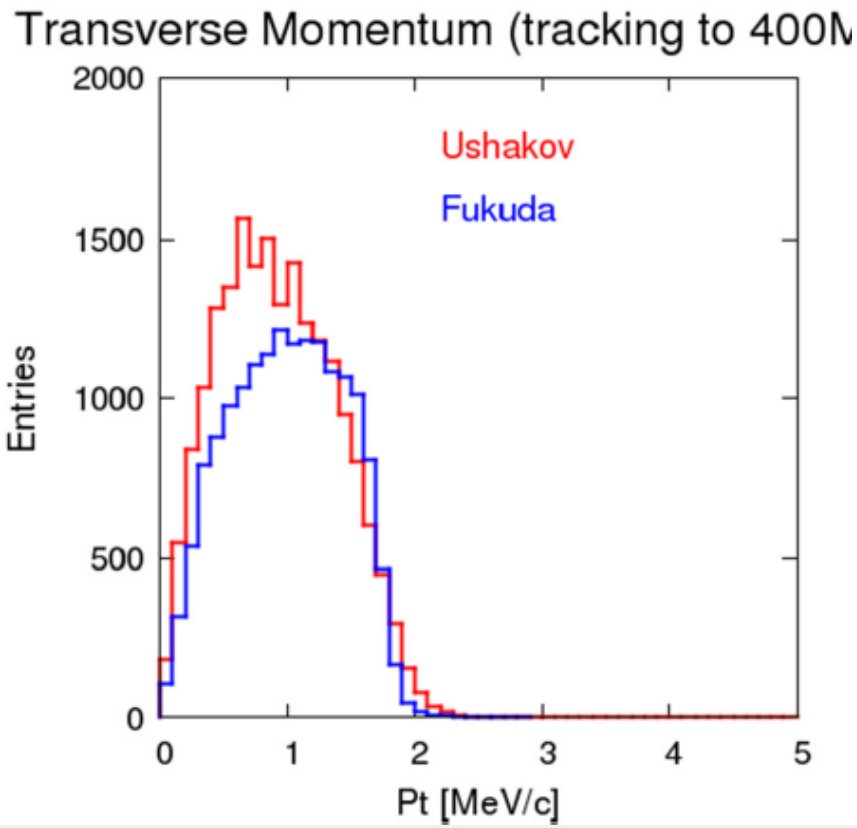
Transported to EC end



Analyzed by T. Okugi

Comparison of 2 simulations





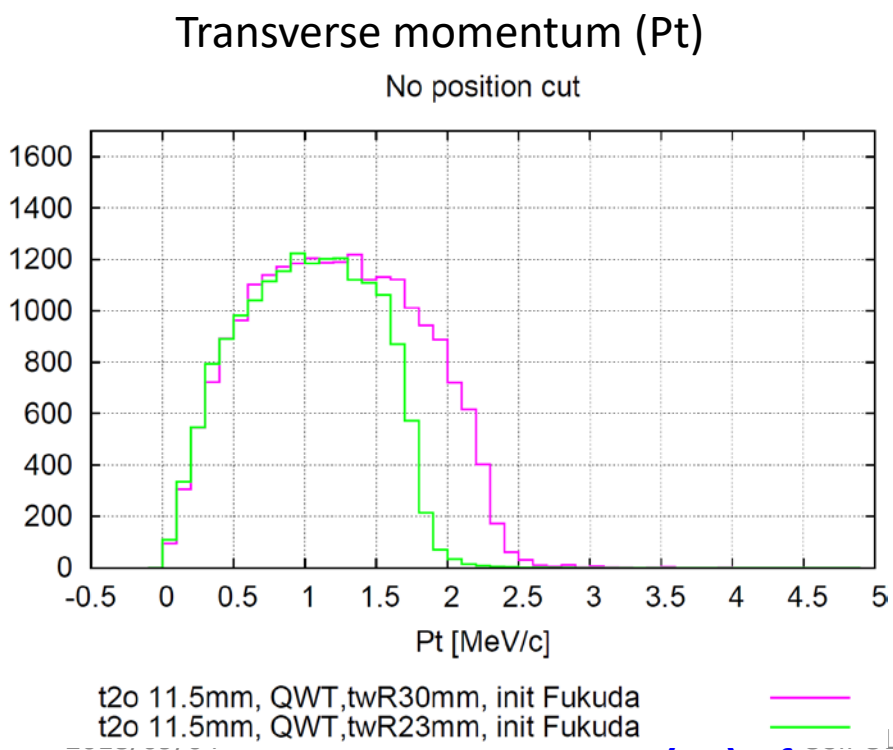
Transverse momentum(Pt) distribution in the low energy region is totally different.

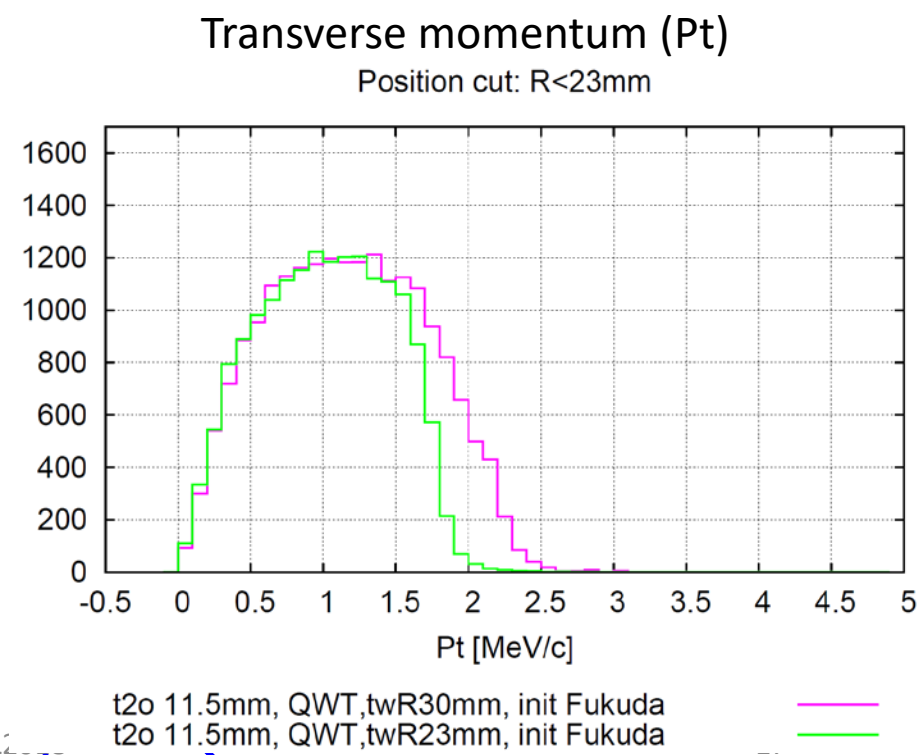
After tracking 400MeV, the upper limit of transverse momentum is the same.

Analyzed by T. Okugi

Transverse momentum when the aperture(2a) of TW is 60mm

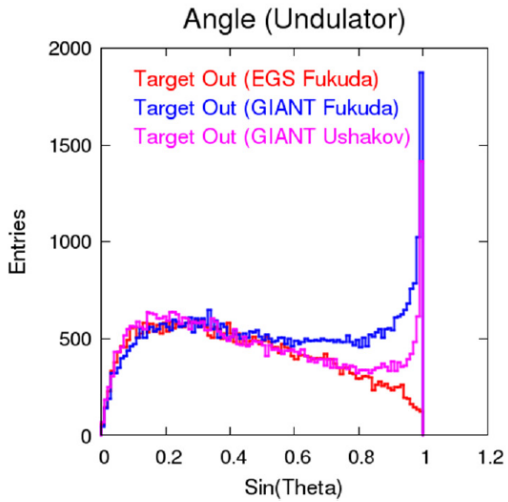
I calculated positrons distribution after capture section when the aperture(2a) of TW tube was changed from 46mm to 60mm.
In this case, the maximum of Pt became 2.5 MeV/c. However, the distribution around 1MeV/c is different yet.

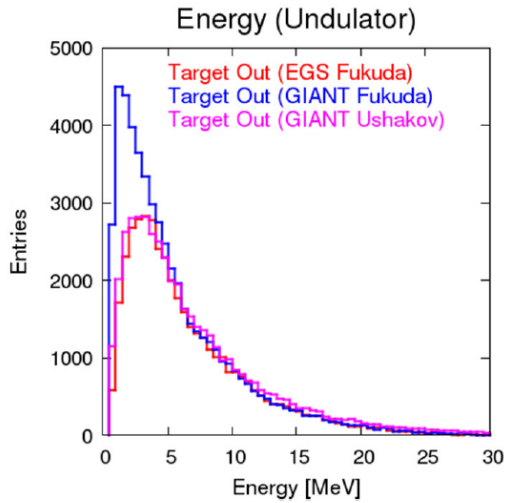




Aperture(2a) of TW tube: 46 → 60mm

Comparison of positron distributions at the exit of a target

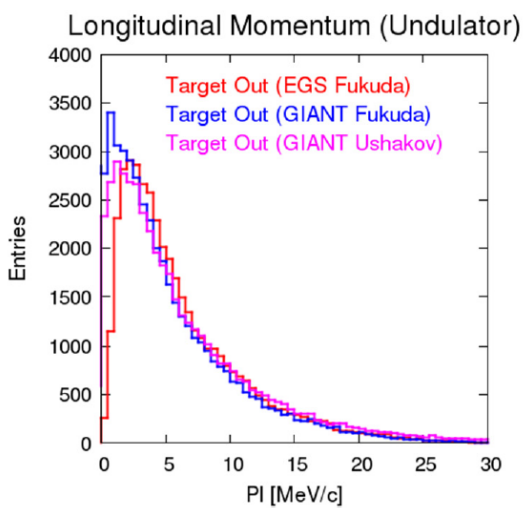


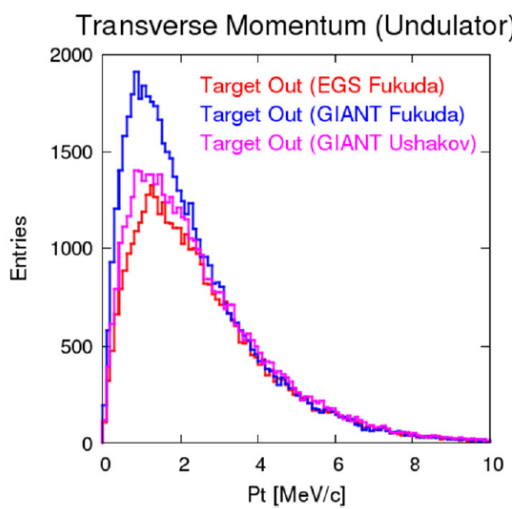


In the region of large angle, the distribution is different.

The effect is caused by the magnetic field on the target.

If the magnetic field is zero, The distribution is almost same.





I thank Ushakov-san for sending me the data of positron simulation.

Analyzed by T. Okugi

Transverse momentum

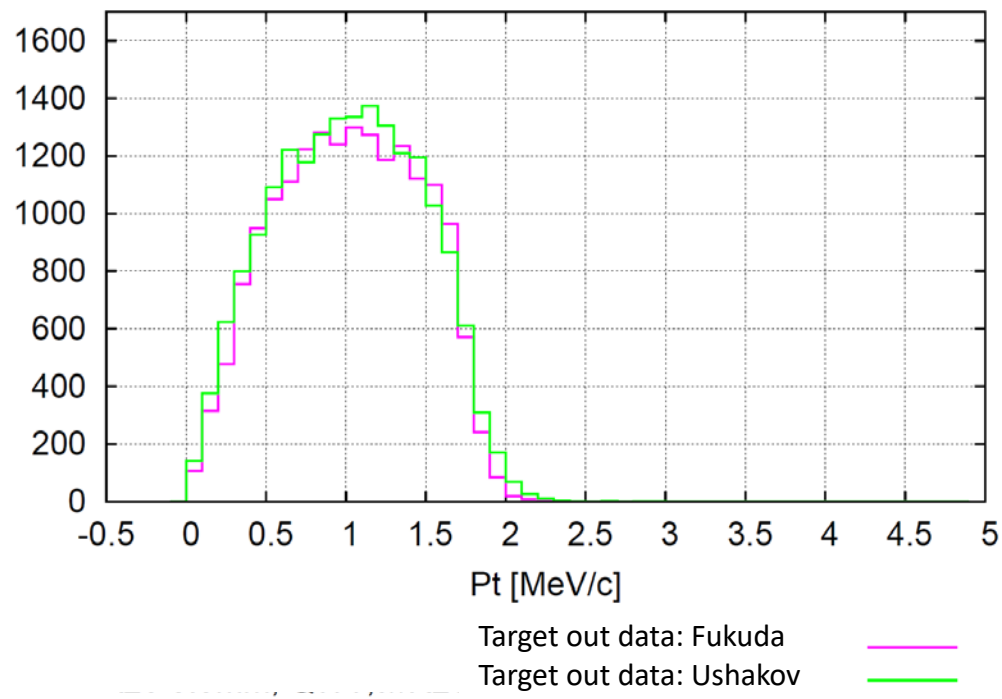
I tracked the positrons using the Ushakov-san's positron data at the exit of a target.
However, the transverse momentum distribution of positrons was not changed.
I could not reproduce the result he calculated.

Number of e+ at the exit of a target
4.5e4 (M.Fukuda)
4.7e4 (A.Ushakov)

Target：**Ti6Al4V, 7mm**
OMD: **QWT (Peak 1.04T)**
Solenoid: 0.5T (capture section)

Accelerating tube : SWx2 + TWx3
SW: Eacc: 15.2MV/m
TW: Eacc: 7.3MV/m

Transverse momentum distribution of positrons at 125MeV



Summary

- The tracking simulation up to the exit of Capture section (125MeV)
  - The yield of positrons in my simulation is different from the Ushakov-san result.
  - Positron yield(e+/e-): 1.3 (Ushakov) , 0.8 (Fukuda)
  - Transverse momentum distribution is different.
  - It has not been clarified why the difference is occurring.
  - To investigate the reason, I am preparing the positron tracking simulation by using GPT code.
- Development of the simulation for positron source
  - The simulation of positron source for e-driven scheme (ILC and SuperKEKB)