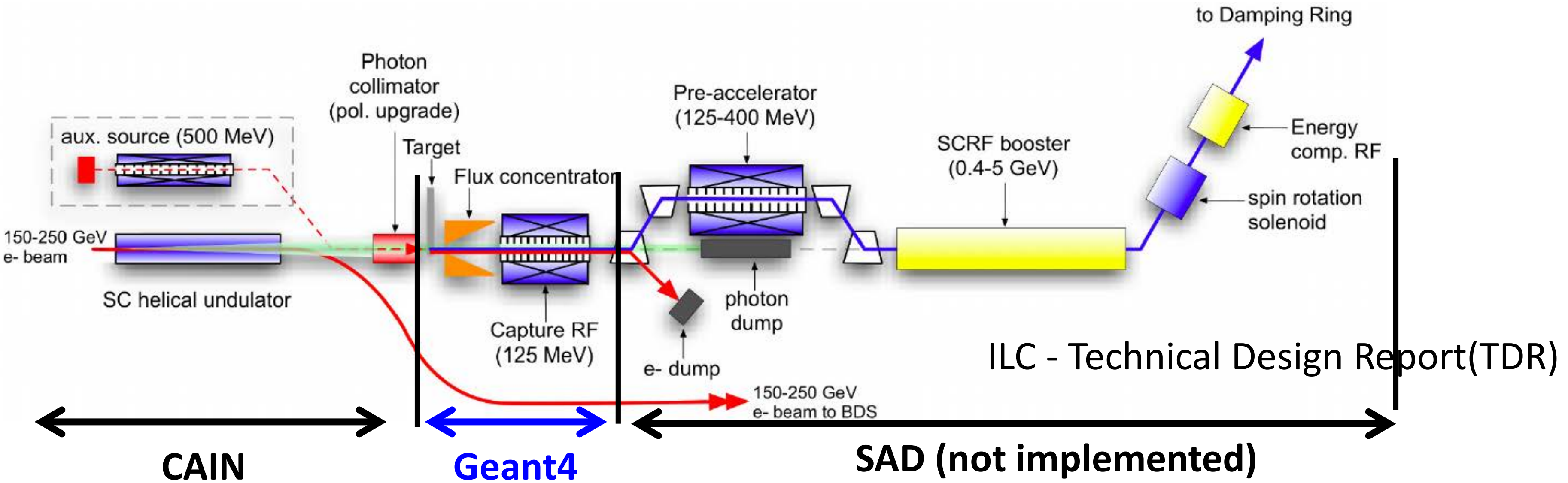
Undulator Positron Source Capture Simulation

KEK M. Fukuda

Simulation of a positron source for undulator method

I am developing start-to-end simulation programs for ILC positron source.
The tracking of positrons up to the exit of Capture section (125MeV) can be simulated now.



Gamma-ray generation: calculated by K. Yokoya
Positron generation at a target --- Capture section (125MeV): calculated by M. Fukuda
Tracking of positrons after Capture section: T. Okugi
A. Ushakov-san has continued the simulation of Undulator ILC positron source all the time.

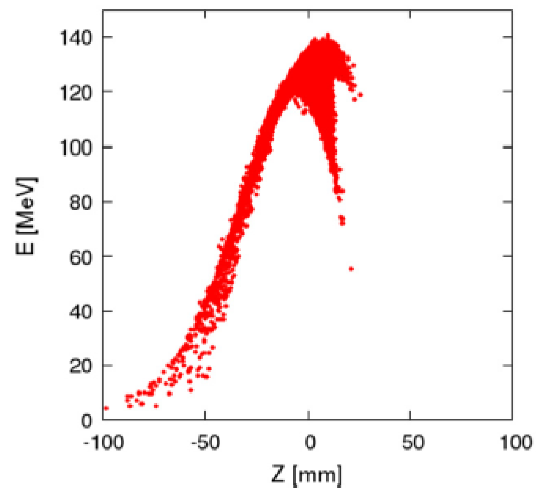
Tracking Simulations

simulated by Andriy Ushakov

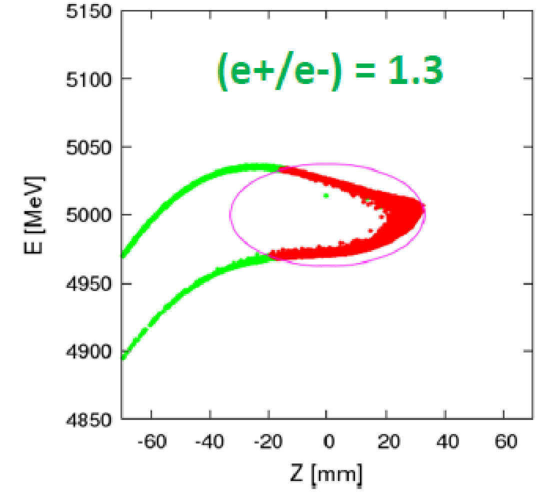
Used parameters are:

**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



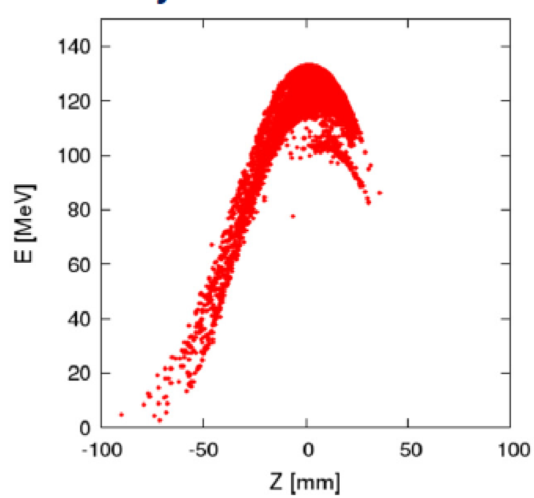
Transported to EC end



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



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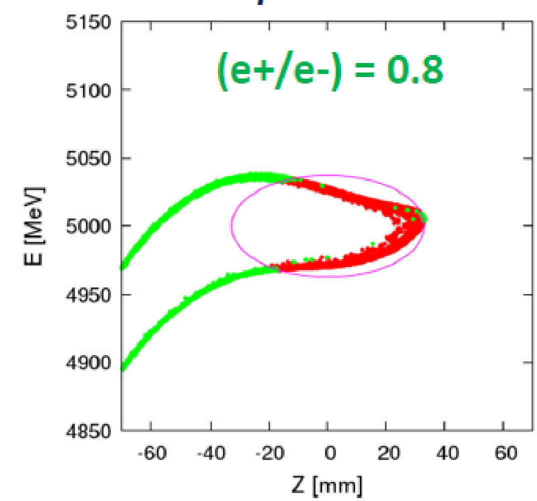


Analyzed by T. Okugi

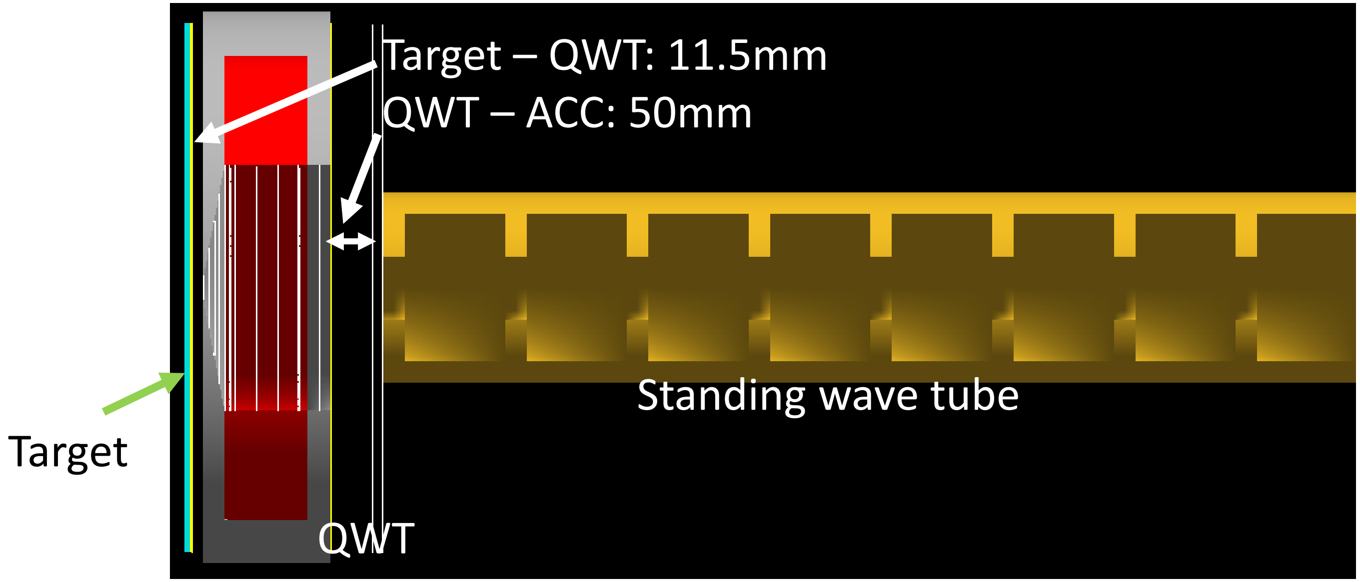
LCWS2018: M. Fukuda

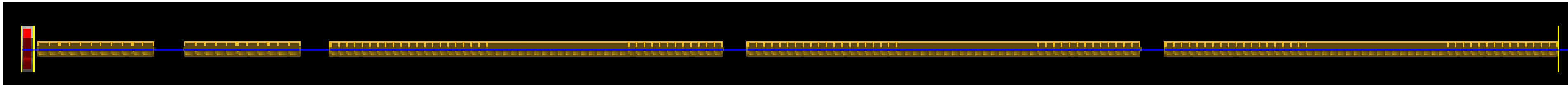
Difference between Fukuda’s simulation and Ushakov-san’s simulation

- The positron yield between Ushakov-san’s simulation and my simulation is different in undulator scheme.
- The difference is caused by the difference of the model of the QWT magnetic field and the accelerating tubes.
- Fukuda’s simulation
  - QWT and the solenoid field designed by Wanming Liu.
  - Capture linac: two SW and three TW accelerating tubes.
- Ushakov-san’s simulation
  - QWT and solenoid field: Simple shape like trapezoid.
  - Capture linac: one long SW accelerating tube.
- I could reproduce the Ushakov-san’s result by using Ushakov-san’s model of QWT and an accelerating tube.

Placement of the QWT and an accelerator (Fukuda)

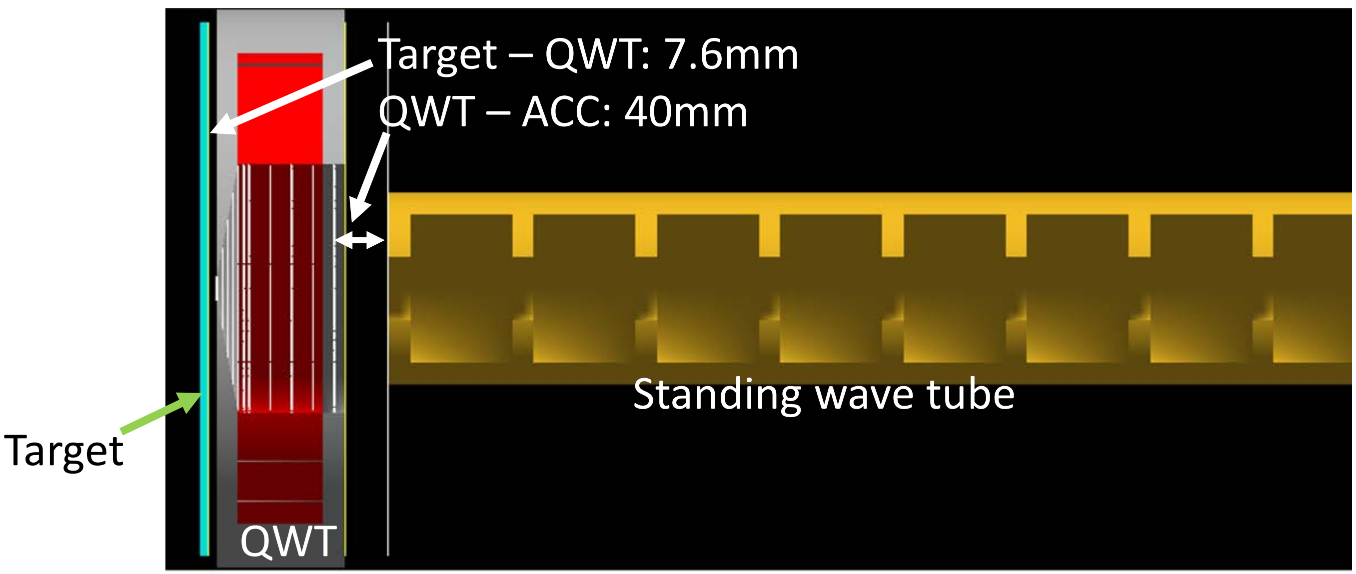
I input this geometry in my simulation.
This placement is different as that of Ushakov-san' simulation.
Positrons are accelerated by two SW accelerating tubes and three TW accelerating tubes.

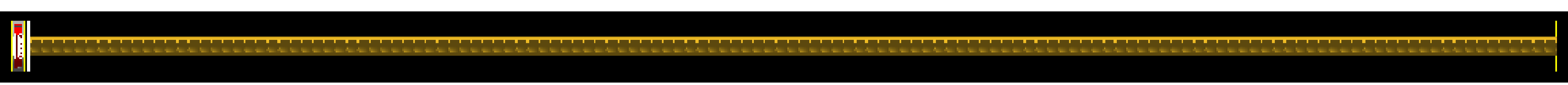




Placement of the QWT and an accelerator (Ushakov)

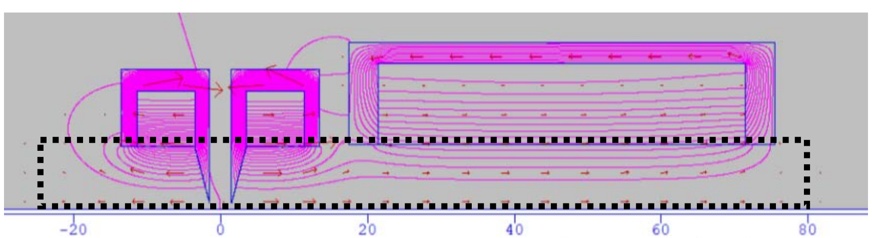
To reproduce the Ushakov-san' result, I changed the geometry in my simulation.
This placement is same as that of Ushakov-san' simulation.
Positrons are accelerated by one SW accelerating tube with the length of ~16.8m.

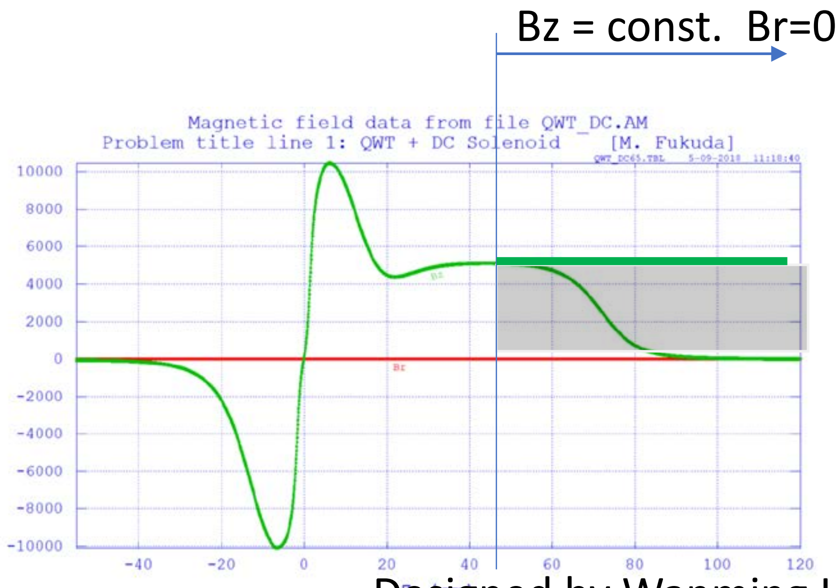




Magnetic field of QWT and Solenoid (Fukuda)

The magnetic field data was calculated by POISSON.
This 2D map data of magnetic field is used in my simulation.
QWT (Peak 1.04T) + 0.5T (capture section)
After z = 444.5mm, Bz = const. (~0.51T), Br =0

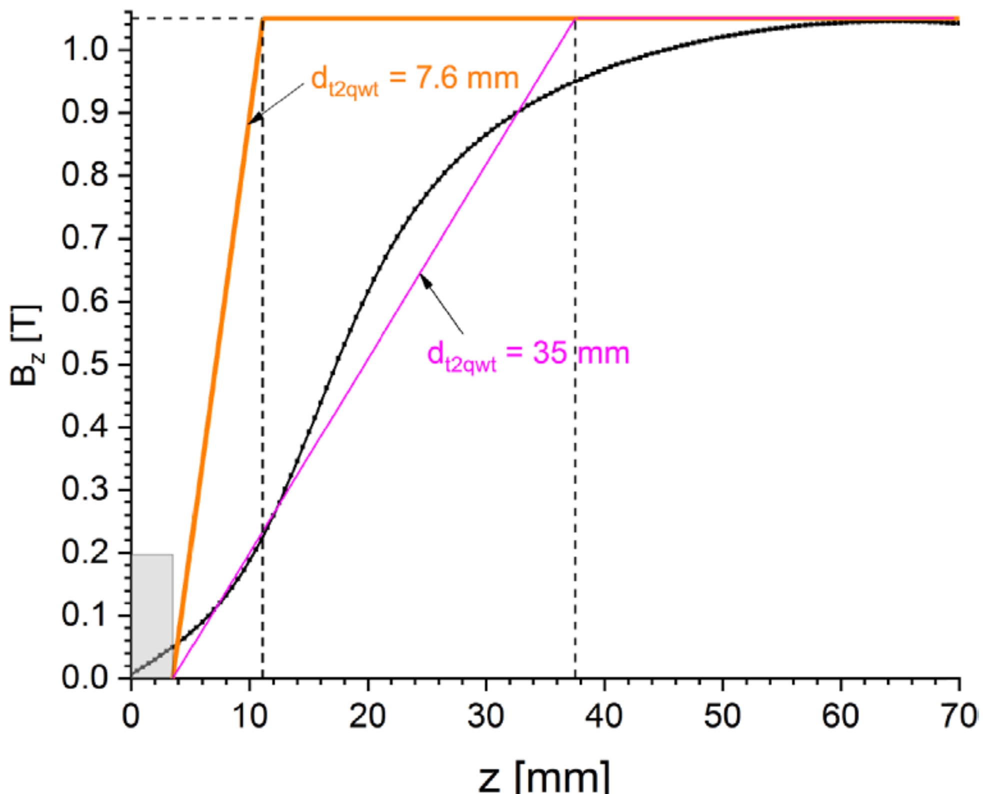


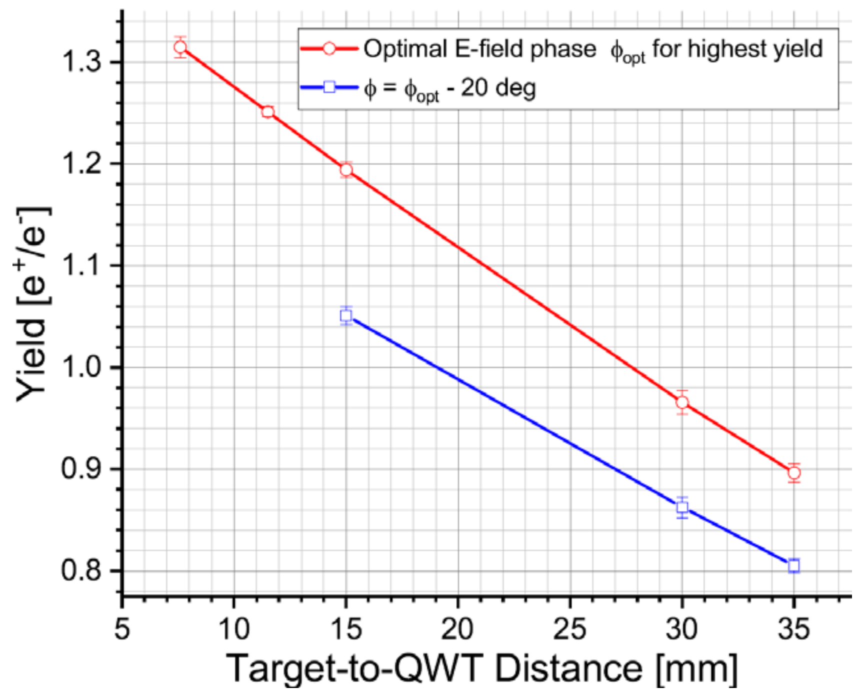


Designed by Wanming Liu
Recalculated by Fukuda

Magnetic field of QWT and Solenoid (Ushakov)

The magnetic field model is different between Ushakov-san’ simulation and mine.
Bz profile is like trapezoid in Ushakov-san’s simulation.
QWT (Peak 1.04T) + 0.5T (capture section)





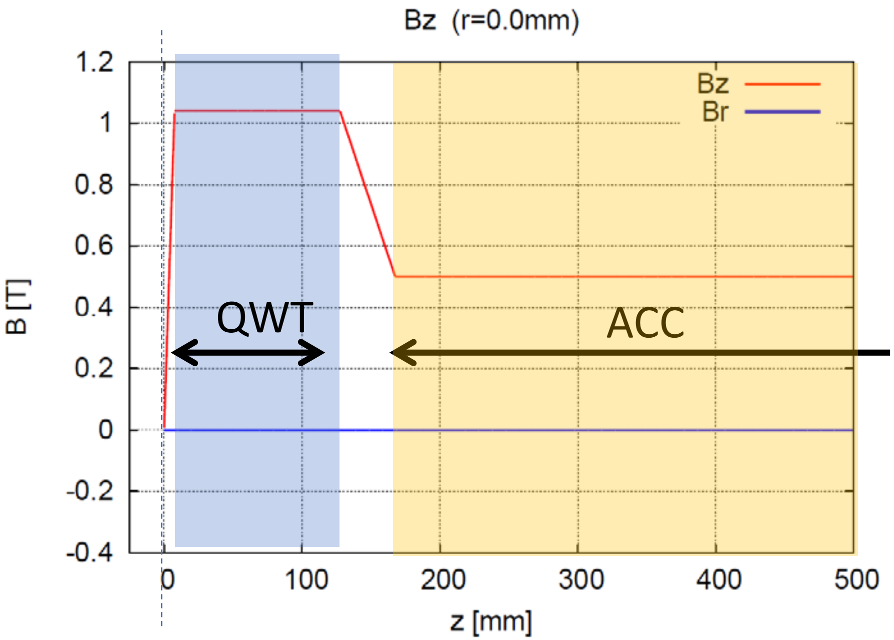
From Ushakov-san

Magnetic field of QWT and Solenoid (**Simple shape**)

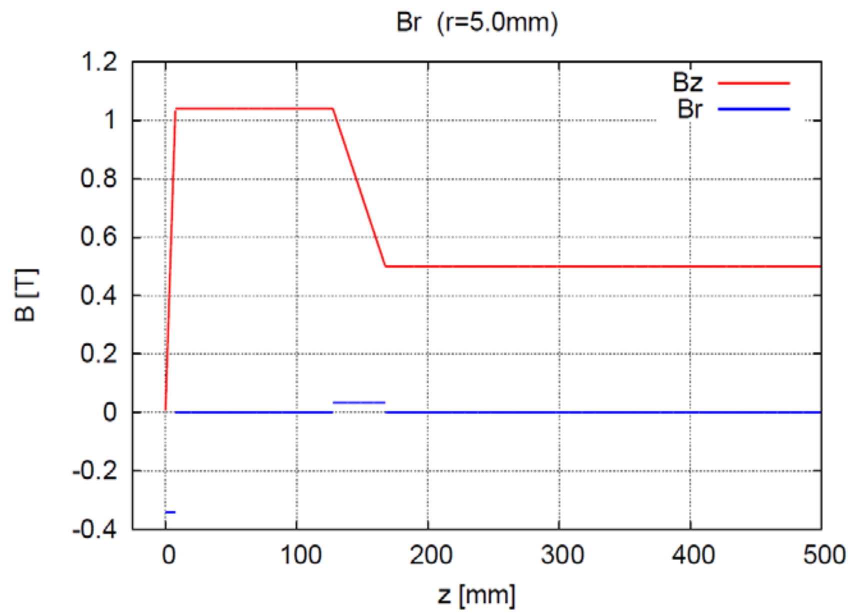
I input the magnetic filed of simple shape like trapezoid.

- Bz=0 at the target rear surface(z=0)
- Bz linearly increases up to 1.04T at QWT front (z=7.6mm)
- Bz is 1.04T until QWT end (z=7.6+120 mm)
- Bz linearly decreases up to 0.5T at ACC front (z=7.6+120+40 mm)
- Bz is 0.5T after ACC front.

Input magnetic field (r=0, on z-axis)



Input magnetic field (r=5mm, off-axis)



Parameters of the simulation

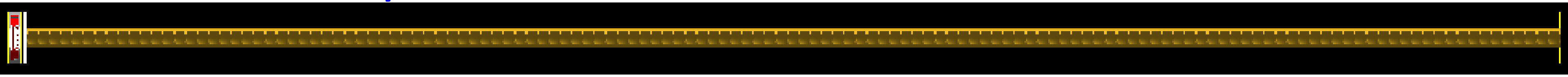
To reproduce the Ushakov-san' result, I simulated with below condition.

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.

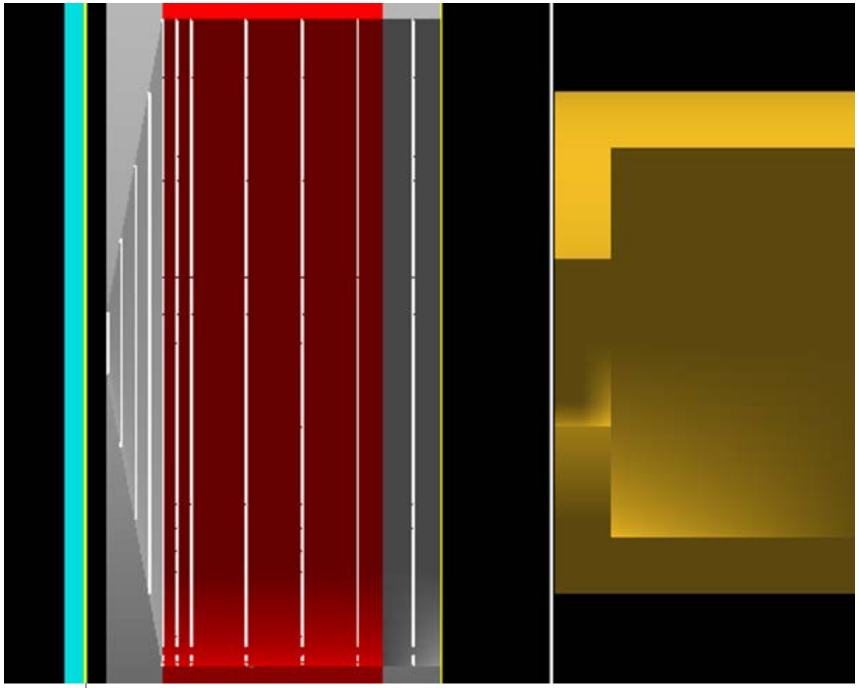
Target ： **Ti6Al4V, 7mm**

OMD: **QWT (Peak 1.04T) + 0.5T (capture section)**
The magnetic filed was calculated by equations **(Simple model)**

Accelerating tube : SWx1 (~16.8m)
Ez = E0*2*sin(omegaspace*(z-zfrontRF)*cos(omegatime*t+Ephase)
omegaspace = k = $2\pi/\lambda$
omegatime = $\omega = 2\pi f = 2\pi c/\lambda$
λ=230.60958mm (L-band)
2*E0: 16.08MV/m



Detector position at Before RF1



Z=0
Target rear surface

BeforeRF1　Z= 167.6mm

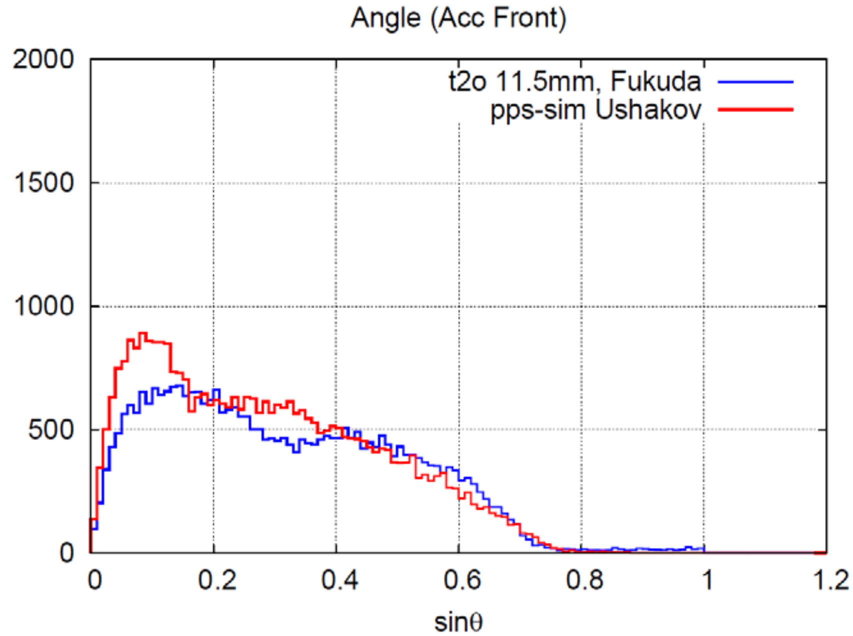
I compare the positron distribution at before RF1.

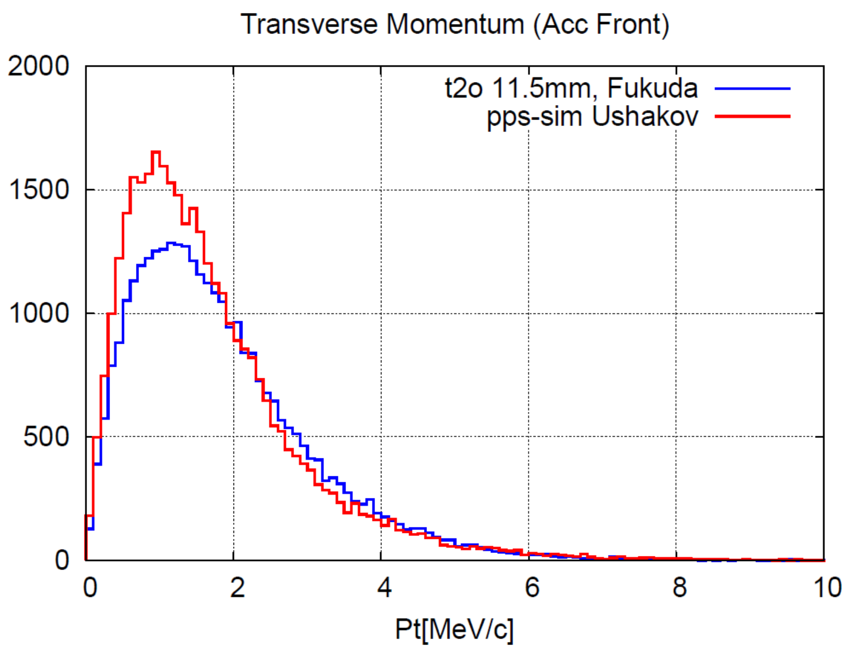
ACC Front

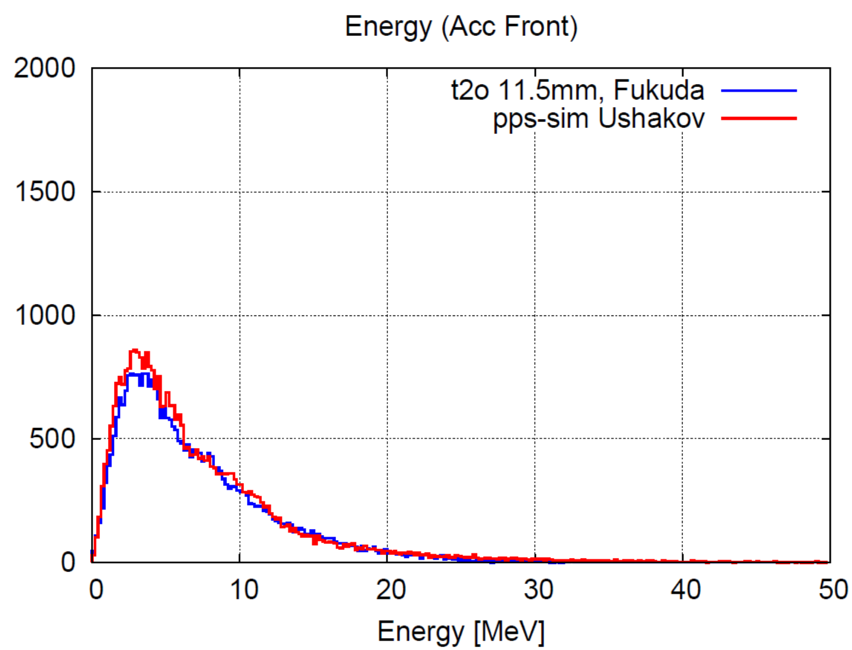
Magnetic field: 2D map data (POISSON)
Z=167.6mm (BeforeRF1)

Ne+: 31877(Fukuda), 34970(Ushakov)
difference: 10%

The e+ distributions are different.



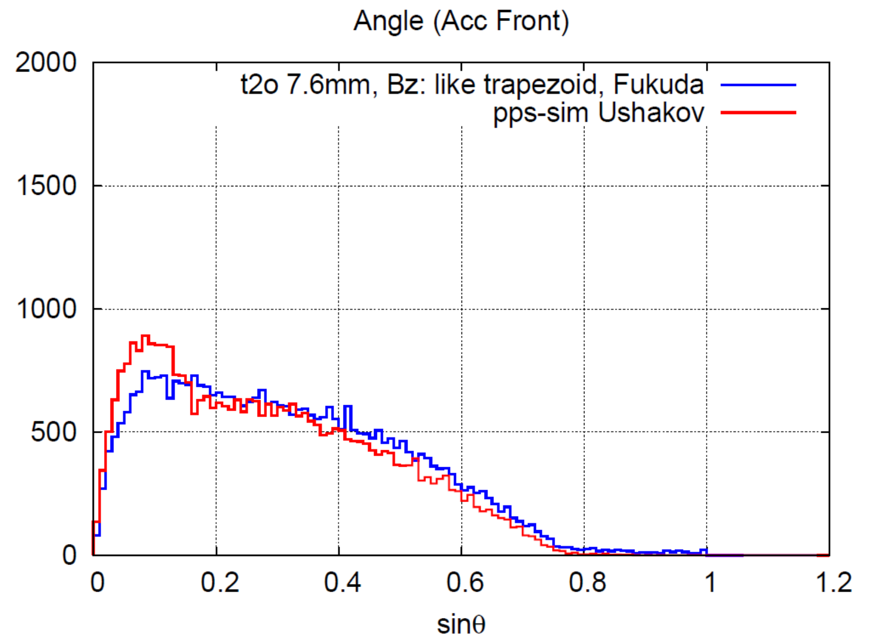


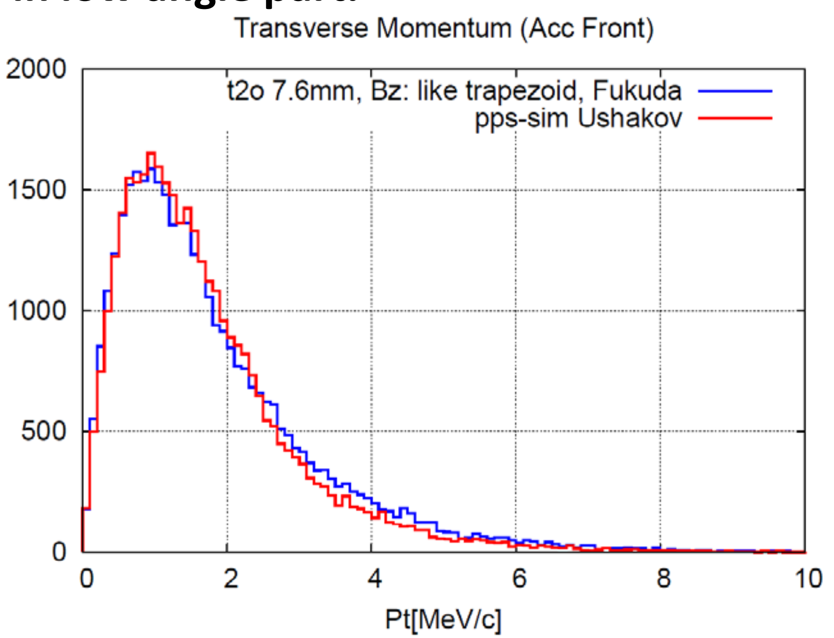


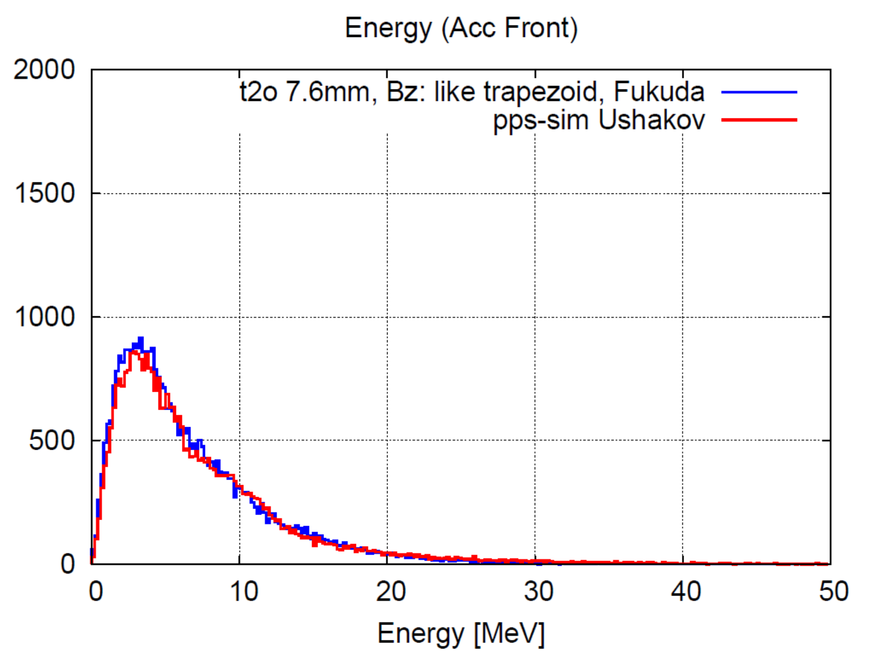
ACC Front

Magnetic field: (Simple shape)
Z=167.6mm (BeforeRF1)

Ne+: 35865 (Fukuda), 34970(Ushakov)
difference: 3%
The e+ distributions become same shape.
In angle distribution, there is difference in low angle part.

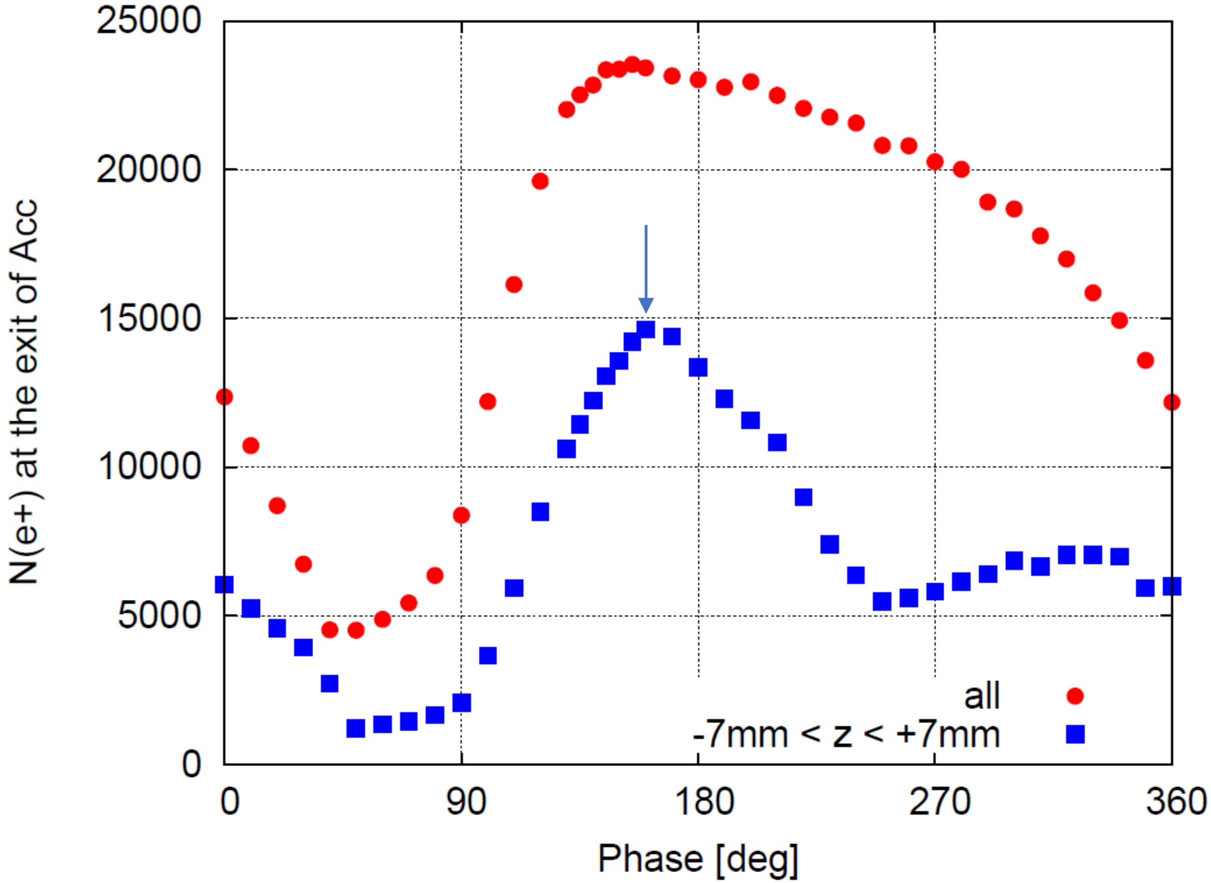






Phase scan result

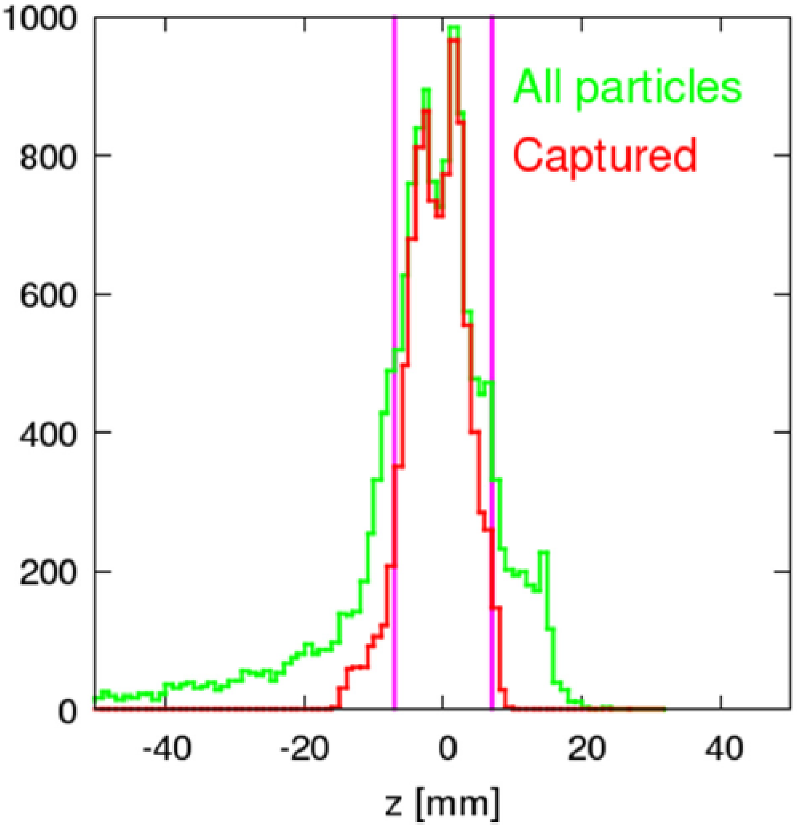
I scanned the accelerating phase to find the best phase.
Number of positrons becomes maximum at 160deg.



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 from the peak of longitudinal position distribution are captured in DR.



The phases of all the accelerating tubes were simultaneously moved.

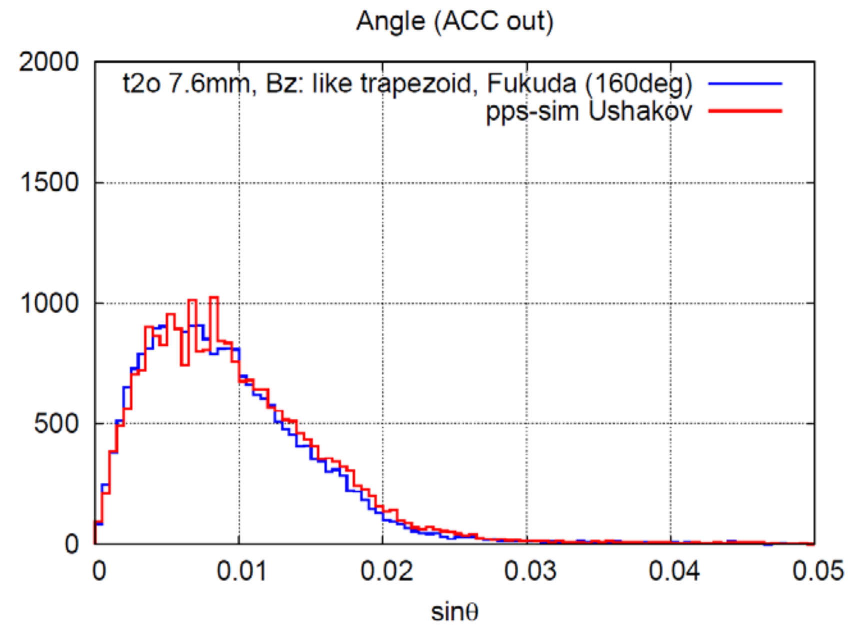
Analyzed by T. Okugi

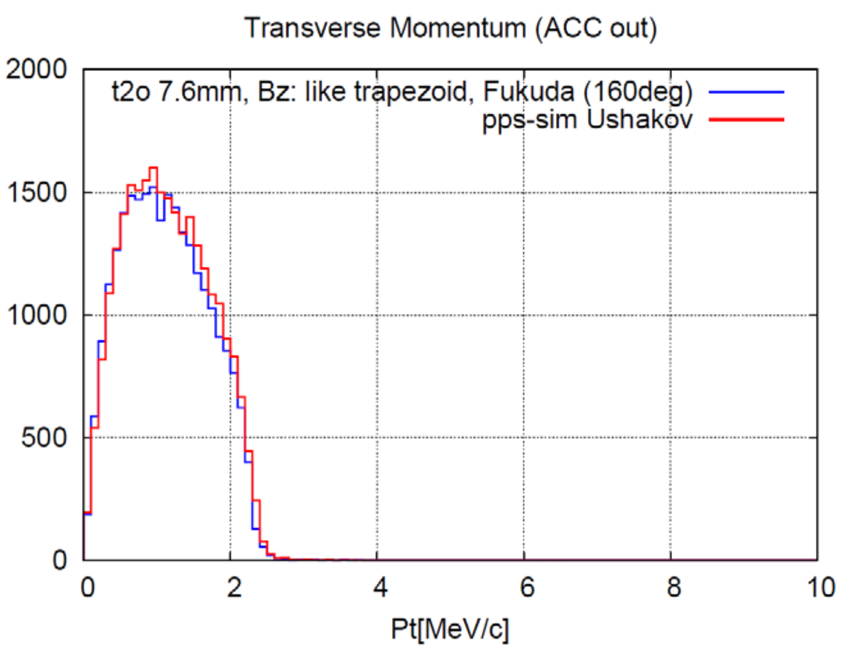
ACC Exit

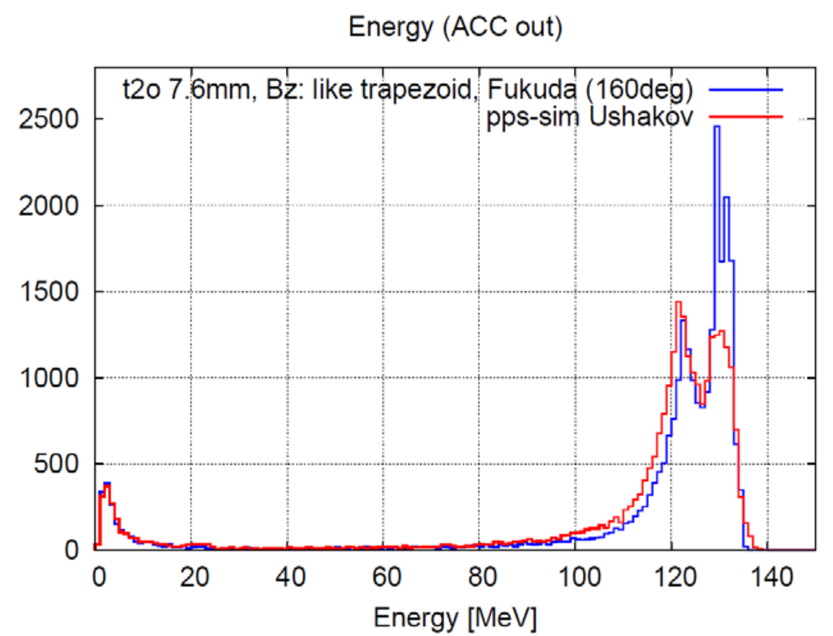
Phase: 160deg

The Pt and angle distributions become similar.
The energy distribution is slightly different.

Ne+: 25460 (Fukuda), 26462 (Ushakov)
difference: 4%



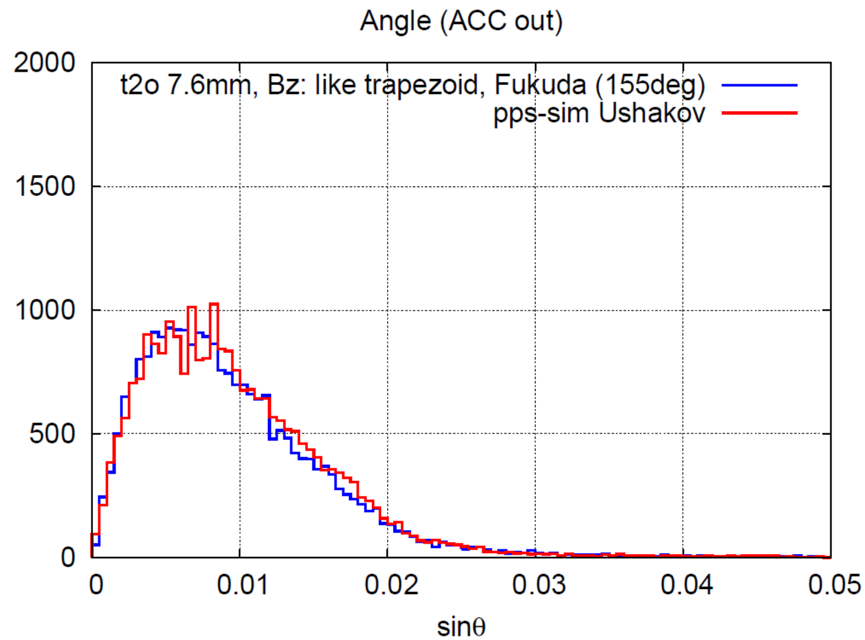


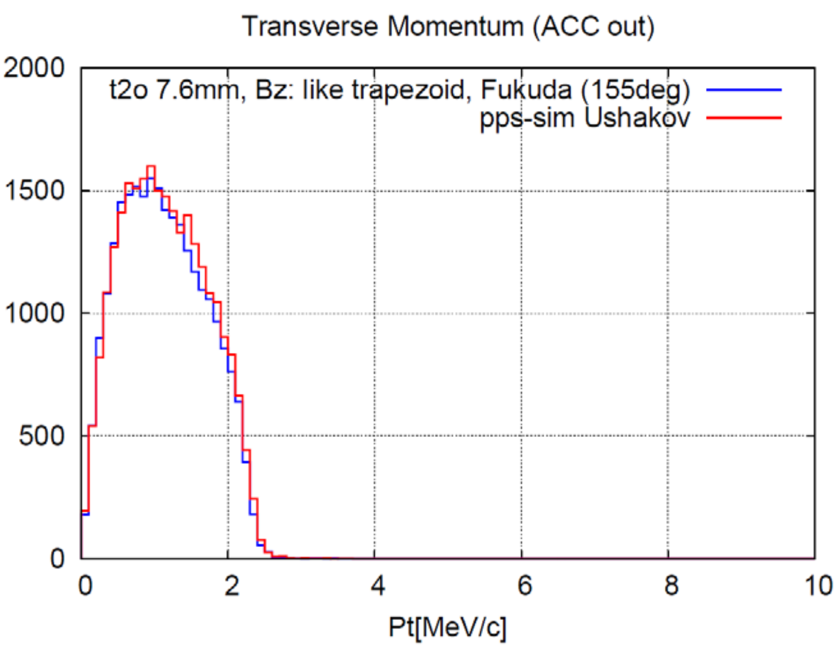


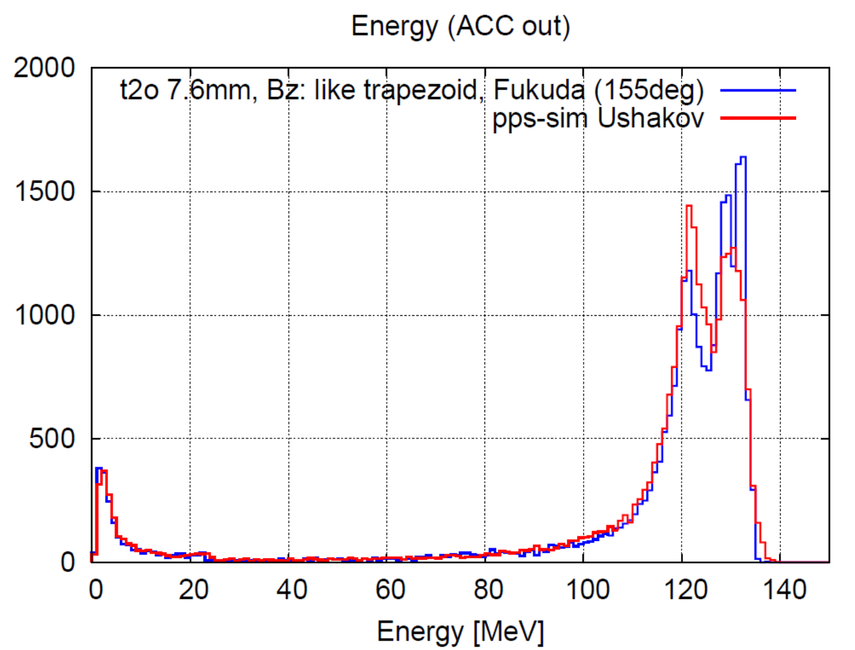
ACC Exit

I adjusted the phase.
Phase: 155deg

The distributions are more similar.
Ne+: 25639(Fukuda), 26462 (Ushakov)
difference: 3%







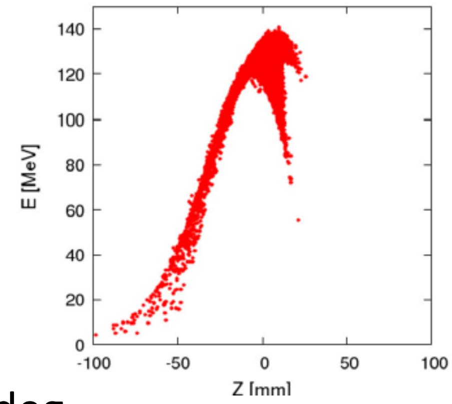
Positron profile

simulated by Andriy Ushakov

Used parameters are:

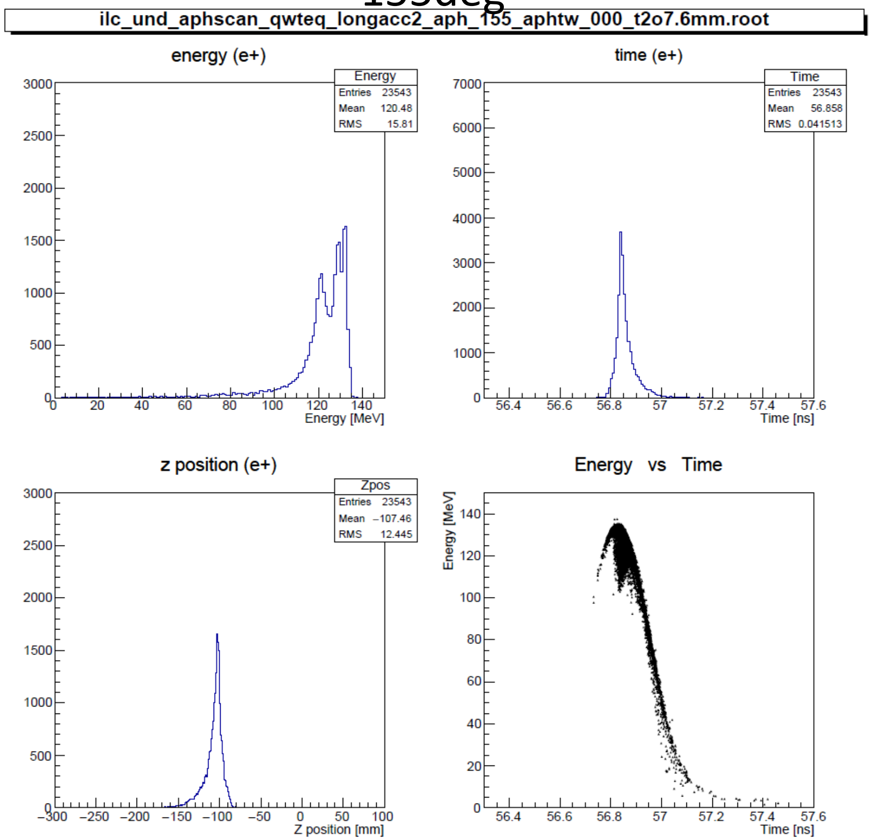
**126.5 GeV e- beam*
** 231 m undulator with K = 0.85*
** 401 m distance between the middle of undulator and the target*
** 7 mm target thickness (Ti6Al4V)*
** QWT with 1.04 T field solenoid downstream the target*
** Deceleation E-field downstream QWT*

Positron profile after 125MeV NC linac

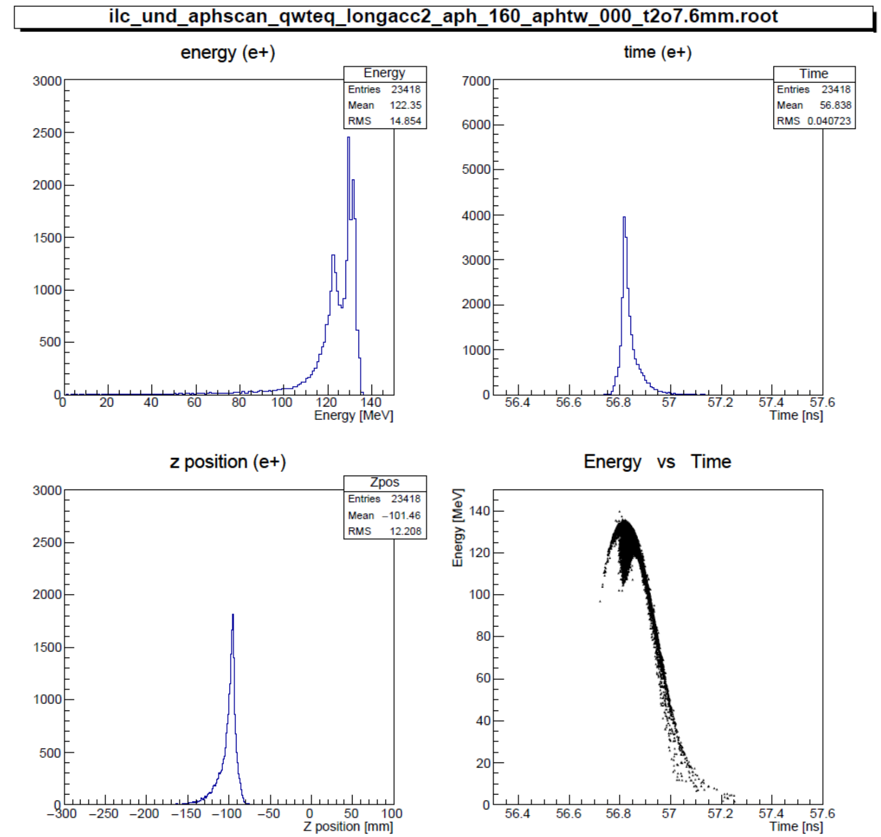


Energy vs time is similar to that of Ushakov-san's simulation.

155deg



160deg



Summary

- I could reproduce the Ushakov-san' result by using the simple Bz profile like trapezoid.
- Hence the positron yield at DR decrease from 1.3 to 0.8 when the magnetic field of the QWT designed by W. Liu-san is used.
- This is not the final result. The optimization of the QWT and solenoid field and so on is not enough.
- I thank Ushakov-san for providing me with useful information and simulation data.