Sep. 24, 2009

Stopped K number optimization study for J-PARC E17 (1)

1. Objective and scheme of the study
2. Optimum z location for WSD
3. Preliminary Monte-Carlo simulation
4. Interim conclusions and things to do

K1.8BR Beamline detector subgroup
for J-PARC E17 collaboration

Objective and Scheme

Objective:

Maximize the stopped K number on the E17 target per primary beam intensity (per SEC, per TM counts).

Scheme:

For **various momentum settings**....

- ✓ Estimate the effects of WSD, including its optimum z location.
- ✓ Evaluate the stopped K number in **changing the z-position of degrader and/or degrader material**

Formalization of stopped $K^{\pm}$ yield

$$N^{\pm}_{\text{stop K}} = I^{\pm}(p_K) \times D(p_K, z_D) \times R^{\pm}(p_K) \times W^{(\pm)}(p_K, \Gamma)$$

$I^{\pm}(p_K)$:Incident Kaon Intensity. It is determined by the primary beam energy/intensity, production target material, extraction angle and beamline acceptance.

$D(p_K, z_D)$: Kaon survival rate by in-flight decay. It also depends on degrader z position. It monotonically increases as the function of p_K and z_D.

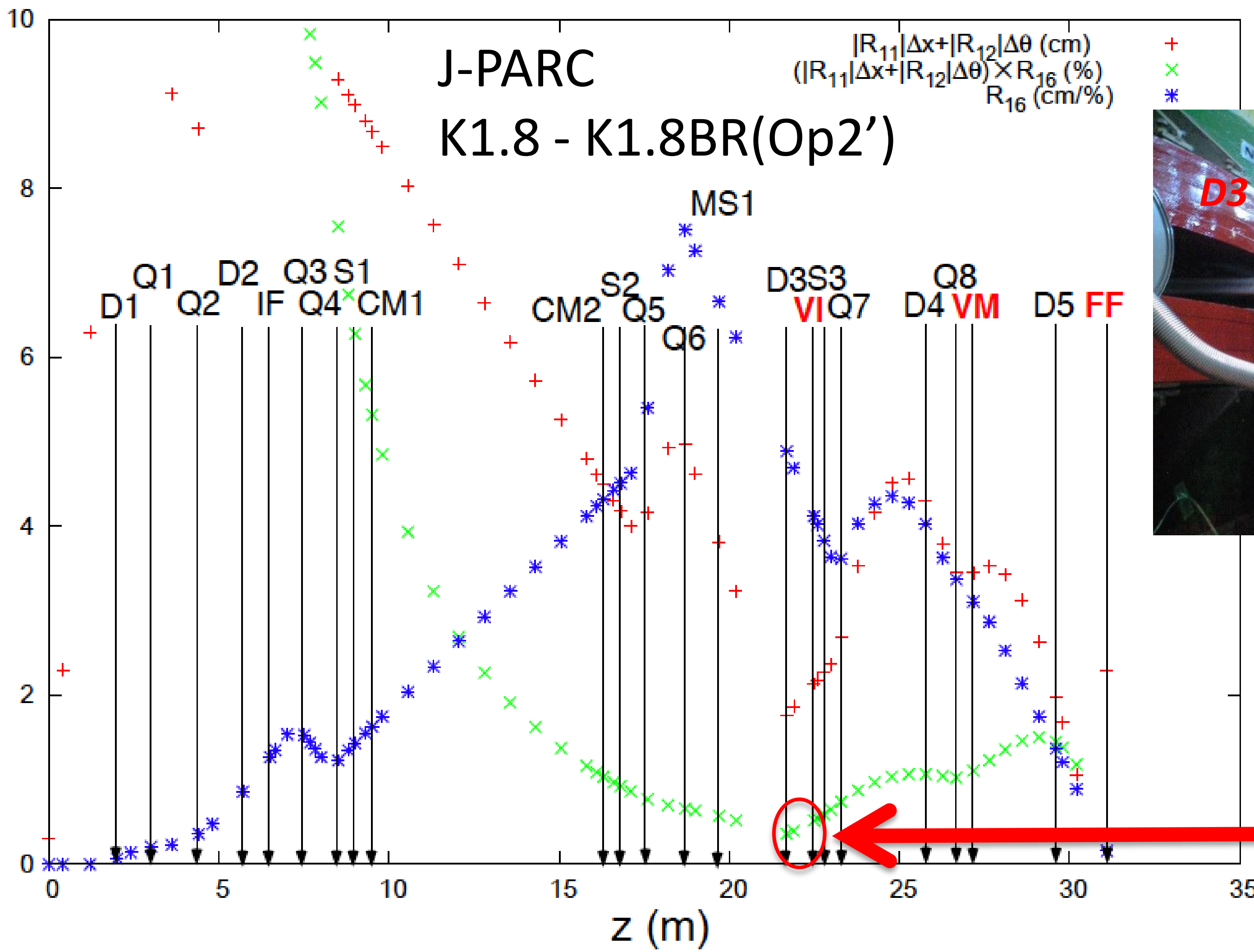
$R^{\pm}(p_K)$: Kaon survival rate from the in-flight reaction in degraders/ target. It monotonically decreases as the function of p_K.

$W^{(\pm)}(p_K, \Gamma)$: Available Kaon fraction to be stopped in the target. For given target thickness, It monotonically decreases as the function of p_K and the width of momentum distribution, Γ. Γ is originally defined by beamline acceptance, but can be tuned with WSD.

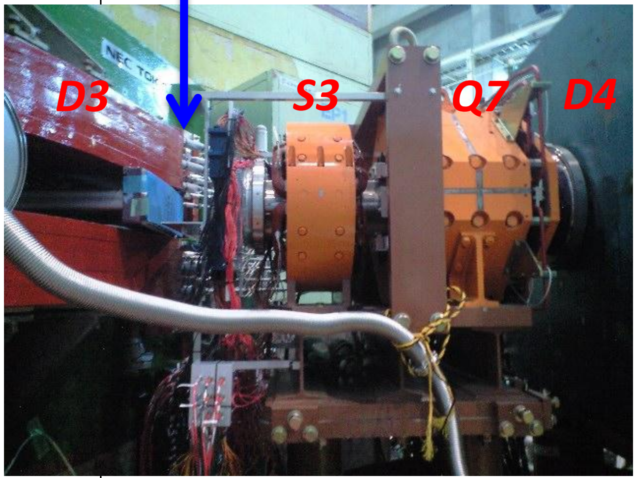
=> Look for Large z_D (downstream) to realize small Γ

Deduction of optimum z location

X’(z) = **R**(z)X(0), X(0) is orbit parameters at the kaon generation (X(T1:z=0)). X=(x, θ, y, ϕ, l, δ), Δx = 0.3 (cm), Δθ = 50 (mrad)



WSD holder is ready at D3out from May.



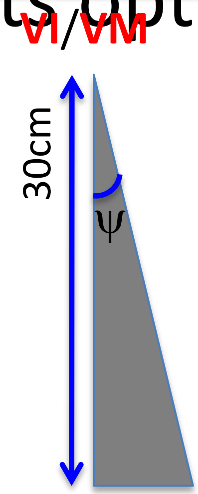
At the ***D3out~VI***, x-p relation is the most close to linear, and R16 takes a moderate value. Momentum fluctuation for given x is **at most 0.3~0.5%.**

Preliminary Monte Carlo

In the preliminary Monte-Carlo, we verify the effect of WSD, including its optimum z position.

$X(VI/VM) = \mathbf{R}_{T1\text{->}VI/VM}X(T1)$

*X(T1):event-by-event
uniform random generation:
x: (-0.3cm, 0.3cm)
θ: (-50mrad, 50mrad)
δ: (-3%, 3%)
*In-flight decay considered



X(VI/VM) ->X'(VI/VM)
event-by-event
by GEANT

$X(D5out) = \mathbf{R}_{VI/VM\text{->}D5out}X'(VI/VM)$

*In-flight decay simulated
event-by-event
*Central momentum is
re-defined by upper-stream-
central momentum + its energy
loss at the x-center

Momentum distributions at D5out are compared

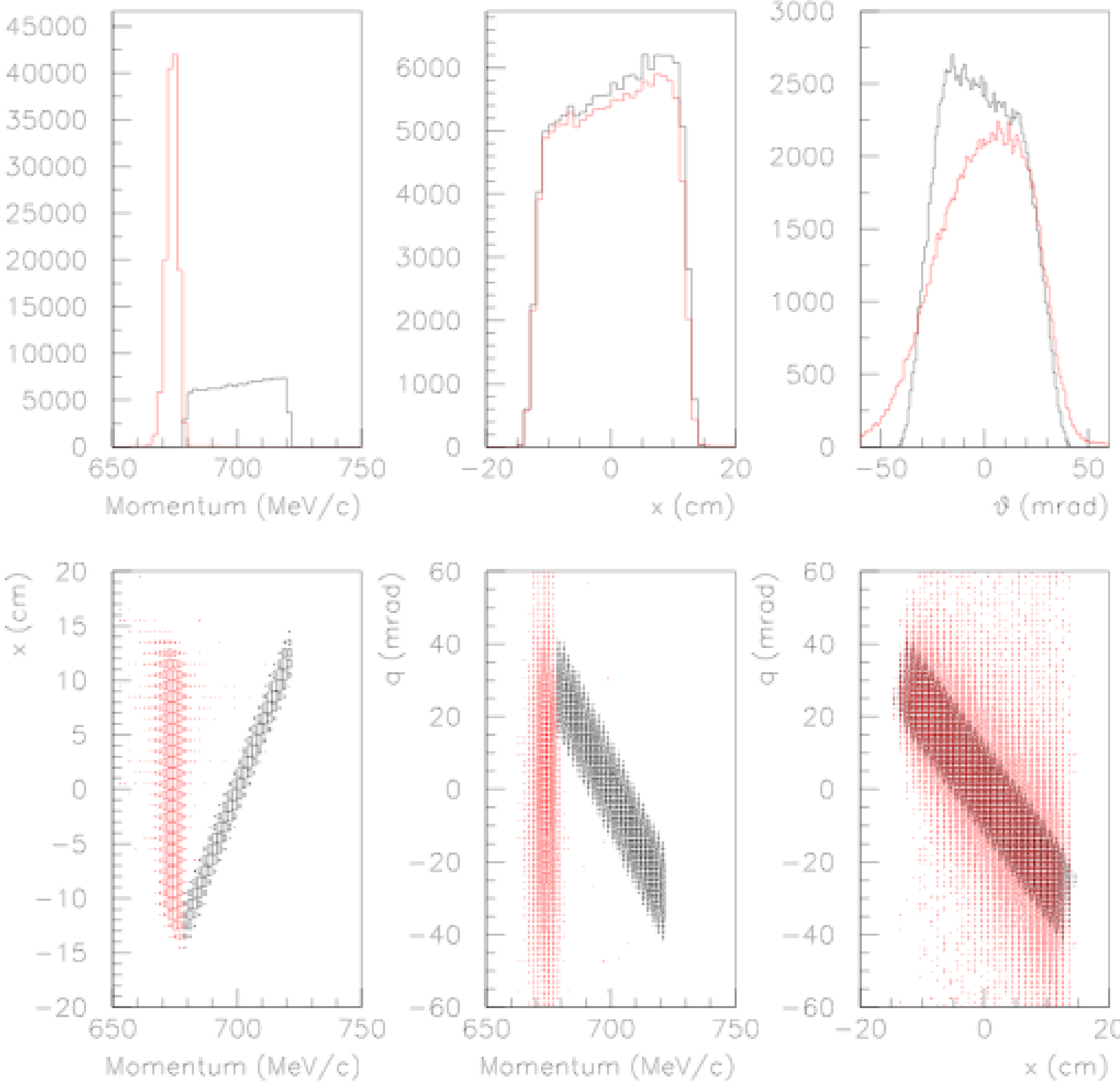
Specification of WSD

If R_{16} is given, WSD shape is unambiguously calculated for each momentum setting so as to compensate energy dispersion by the variation of energy loss –

$$\tan\psi = (dE/dx)_{dispersion} / (dE/dx)_{loss}$$

Kaon Central Momentum (MeV/c)	Energy loss in C (MeV/cm) (@ρ=1.90 g/cc)	Energy Dispersion dE/dx (MeV/cm) VI(R_{16}=4.12)/VM(R_{16}=3.11)	$\tan\psi$ VI / VM
550.	4.783	0.993/1.316	0.208/0.275
600.	4.495	1.125/1.490	0.250/0.331
650.	4.271	1.256/1.664	0.294/0.390
700.	4.096	1.388/1.839	0.339/0.449
750.	3.956	1.521/2.014	0.384/0.509
800.	3.844	1.652/2.189	0.430/0.569
850.	3.752	1.784/2.363	0.475/0.630
900.	3.677	1.915/2.537	0.521/0.690

Beam profile for "WSD at VI" (P_K=700 MeV/c)

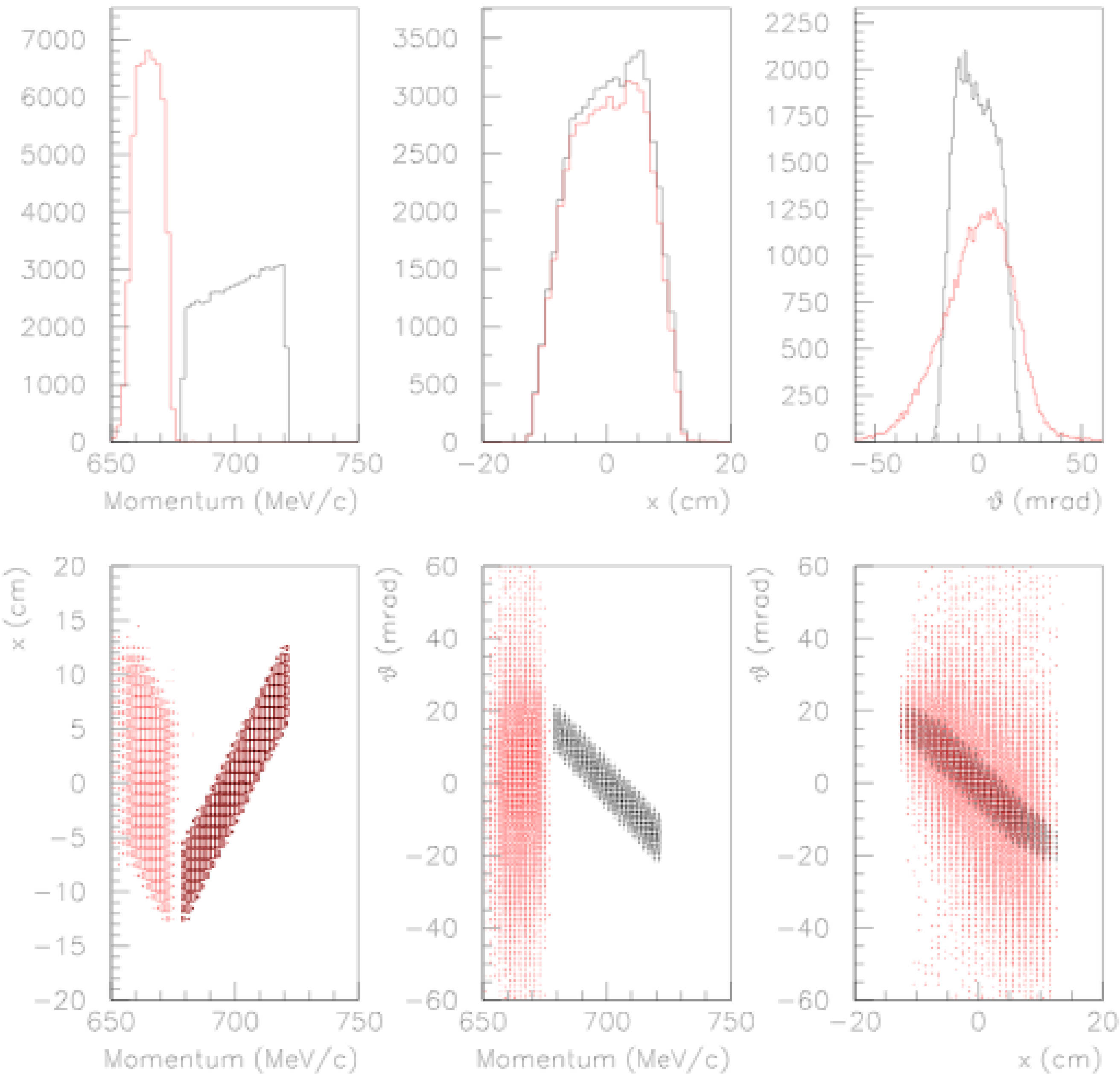


Black: beam profile at just upstream of WSD at VI

Red : beam profile at just downstream of WSD at VI

At downstream, no x/θ –p_K correlation is seen, and p_K distribution is narrowed successfully. The profile is similar for **all incident momenta.**

Beam profile for “WSD at VM” (P_K=700 MeV/c)



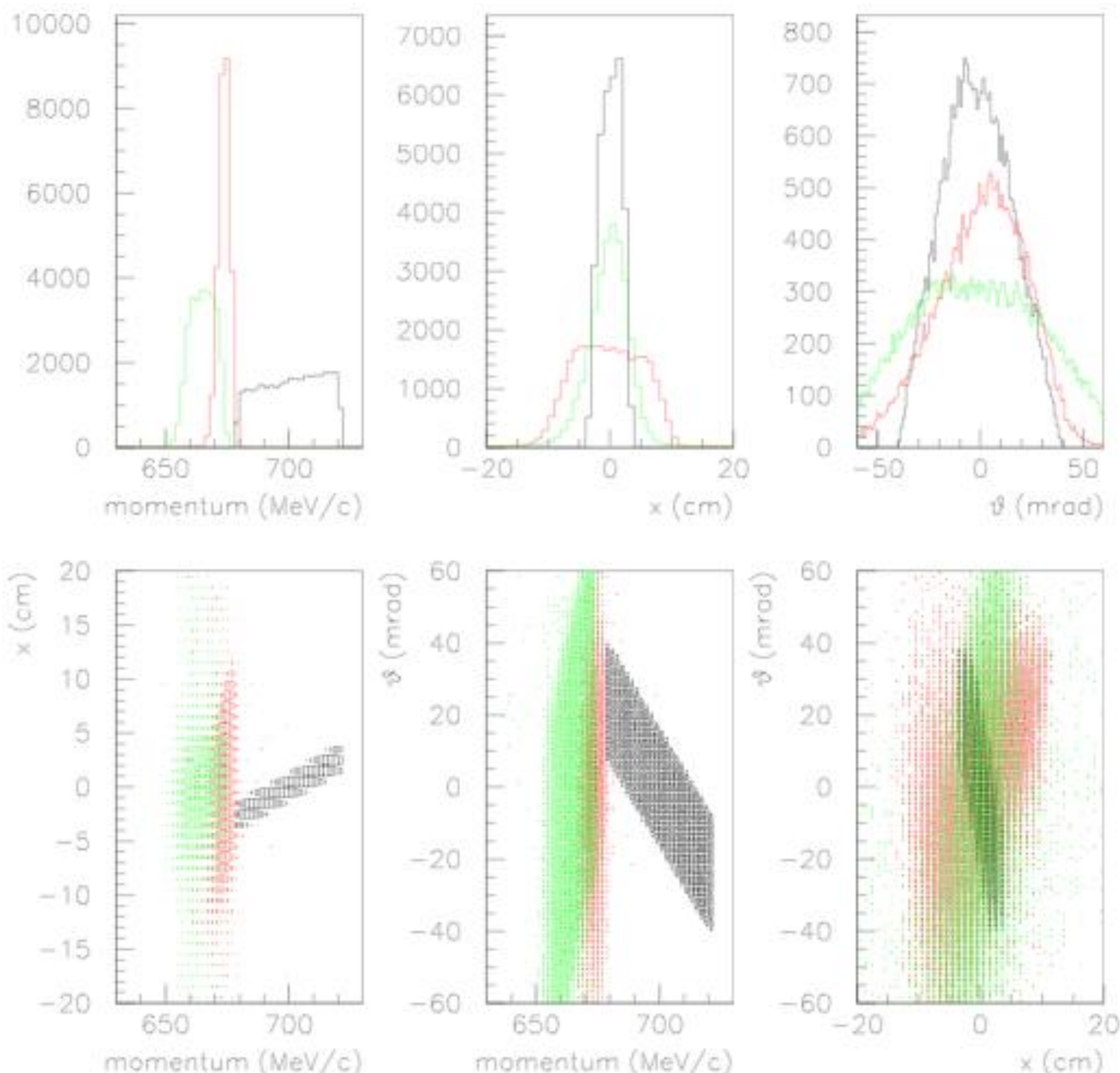
Black: beam profile at just upstream of WSD at VM

Red : beam profile at just downstream of WSD at VM

At downstream, no x/θ –p_K correlation is seen, and p_K distribution is narrowed successfully.

But the improvement is not as drastic as VI.

Beam profile at D5out (T0)(P_K=700 MeV/c)



Black: beam profile at T0 without WSD

Red : beam profile At T0 with WSD at VI

Green : beam profile At T0 with WSD at VM

Improvement of momentum Distribution is remarkable, but as momentum distribution is narrowed, x distribution spreads out in the present optics for in-flight experiment. S3-Q7-D4-Q8-D5 field values should be tuned to focus the beam to the center to maximize the stopped K yield on the tiny target.

Interim conclusions

1. By putting WSD at VI or VM, **momentum distribution is successfully narrowed, and additional decay loss effect seems to be tiny compared to the inferred gain**.
2. For the “WSD-at-VI” setting, it is obvious that **a new downstream optics is advisable to narrow x/θ distributions to maximize stopped K yield**. For “WSD-at-VM” setting, we have no room to tune the downstream (only D5 remains), and “WSD at VI” seems to be unique solution as is understood from the expected gain and the constraint of the space available there.
3. Final gain factor with WSD will be evaluated by 2nd-stage Monte-Carlo to simulate the detector/target region with this 1st-stage result as input beam parameters. Then, this issue is finally concluded.

Further steps to finalize the study

1. Better simulation of incident Kaon beam.

-> Sanford-Wang formula + beamline acceptance.

2. **New downstream optics to minimize x-image at T0.**

3. 2nd step GEANT Monte-Carlo with this (or improved one for beam input as mentioned above) preliminary beam outputs at T0.

-> **Final Decision of WSD placement**

-> **Decision of material/size for main degrader**

-> **Decision of optimum momentum**

-> **Estimation of expected statistics and primary beam intensity to start the production.**