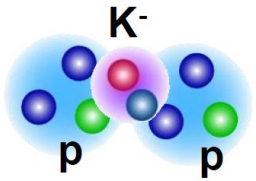


Overview of the J-PARC K10 Beamline

IPNS, KEK / RCNP, Osaka Univ / SOKENDAI
Hitoshi Takahashi

Current HEF

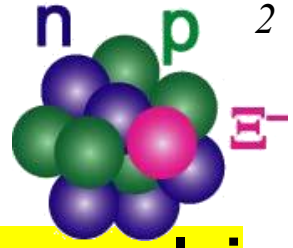


- < 1.1 GeV/c
- ~ 5x10^5 K$^-$/spill
- **Kaon in nuclei**

K1.8BR

K1.8

- < 2.0 GeV/c
- ~ 10^6 K$^-$/spill
- **S=-1 and S=-2 hypernuclei**



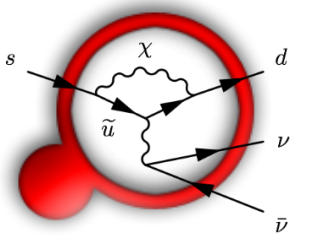
primary proton beams

T1 target

- Au Target
- Indirectly cooled
- max 115 kW (4.24s)
- 101kW achieved

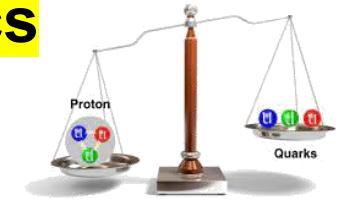
KL

- 16 deg extraction
- ~ 2.1 GeV/c ~ 10^7 K^0_L/spill
- $K_L^0 \rightarrow \pi^0 \nu\bar{\nu}$



high-p

- 30 GeV proton ~ 10^{10}
- **Hadron physics**

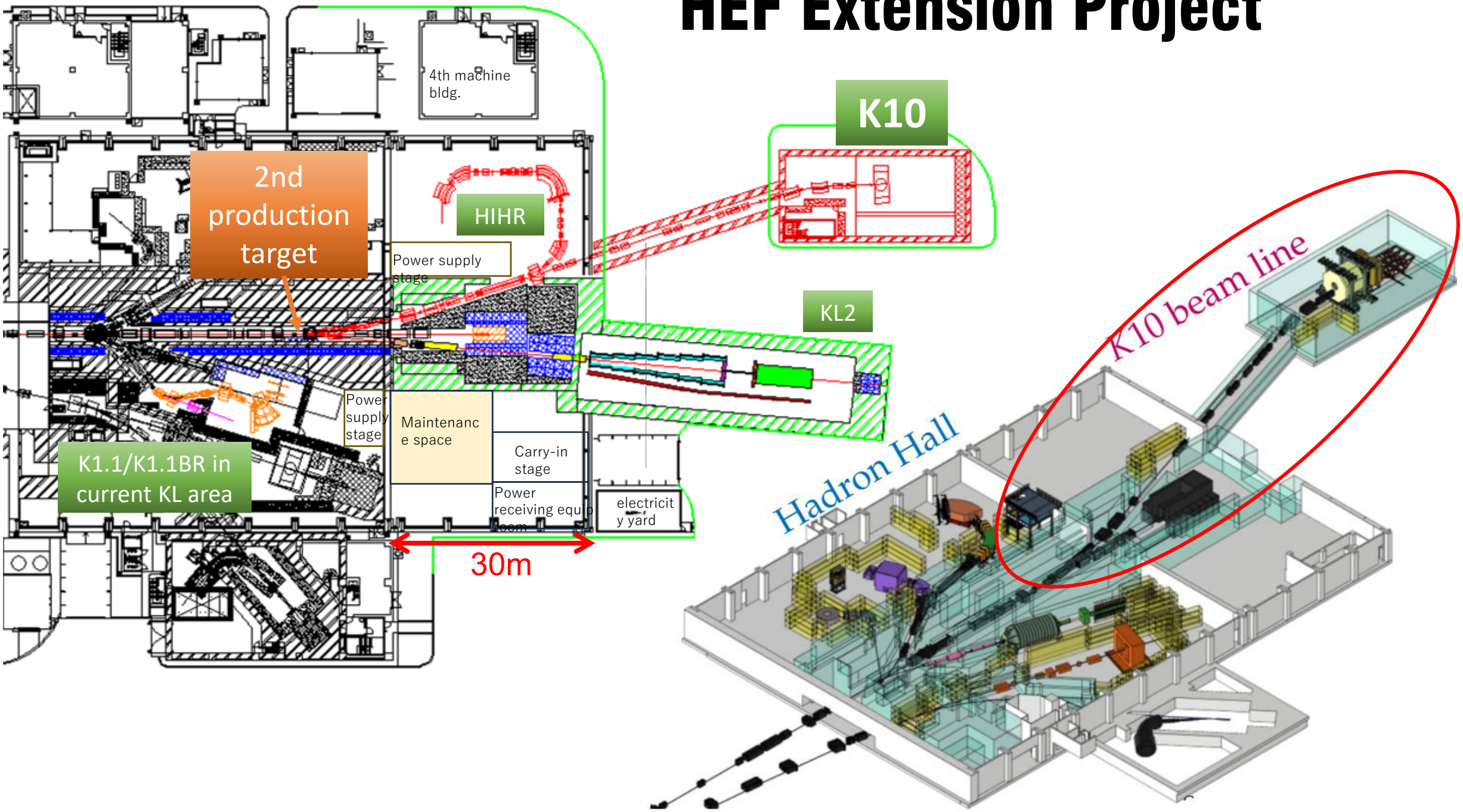


COMET

- μ$^-$ beam
- **μ-e conversion**



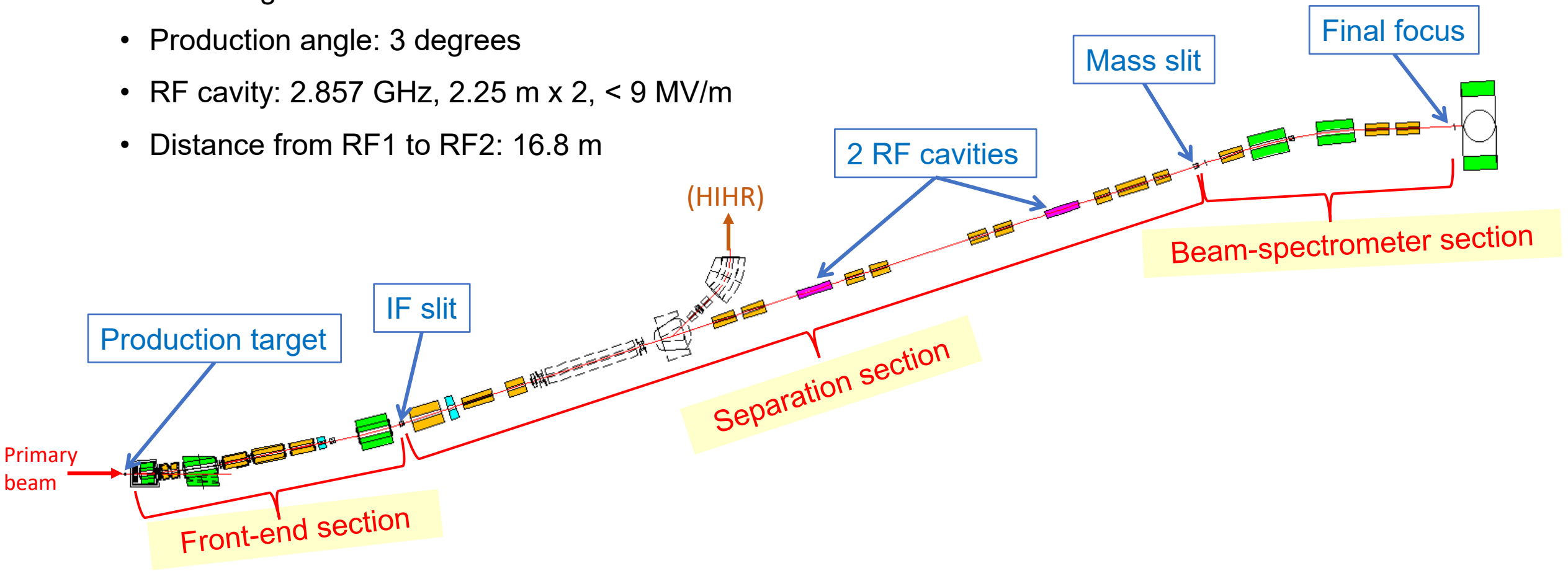
HEF Extension Project



K10 Beam Line

Well-separated high-momentum secondary charged beam line

- Momentum: < 10 GeV/c
- Total length: 90.2 m
- Production angle: 3 degrees
- RF cavity: 2.857 GHz, 2.25 m x 2, < 9 MV/m
- Distance from RF1 to RF2: 16.8 m



RF Separation Method

Deflection with 2 RF cavities:

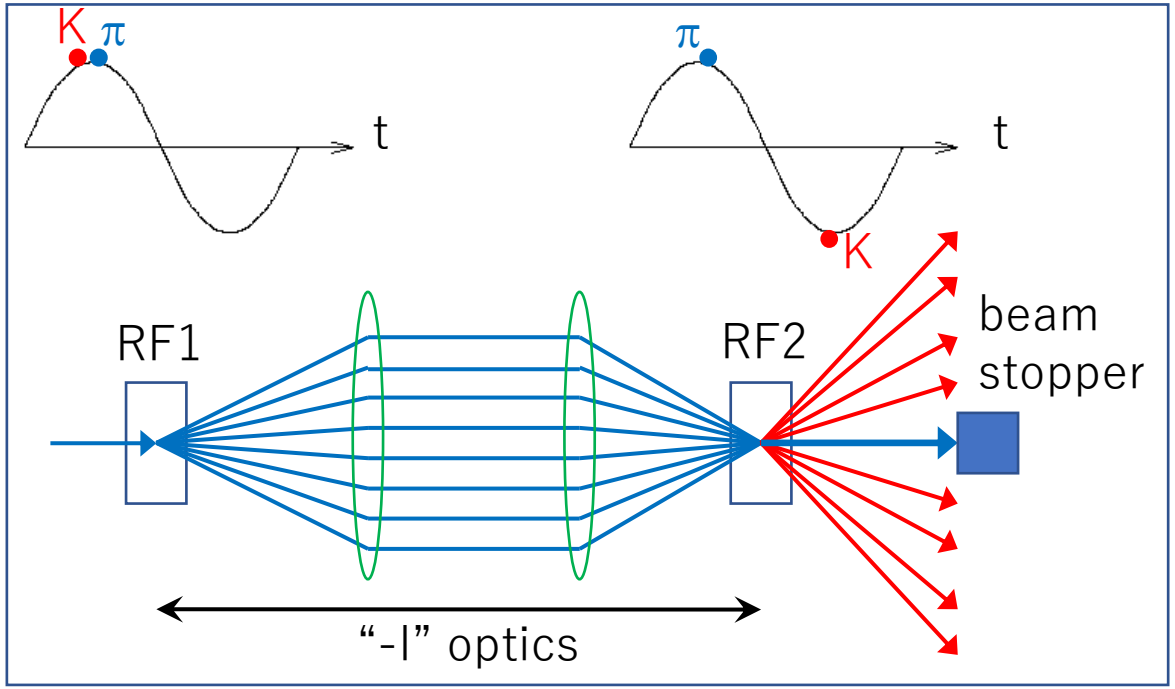
due to "-I" optics from RF1 to RF2

$$y' = -A\sin(\omega t) + A\sin(\omega t + \Delta\varphi)$$

$$= 2A\sin\frac{\Delta\varphi}{2}\cos\left(\omega t + \frac{\Delta\varphi}{2}\right)$$

$$A = \frac{eEl}{pc\beta}$$

ωt: entry phase at RF1
$\Delta\varphi$: phase diff. btwn RF1 and RF2
e: charge
E: field gradient
l: length of cavity
p: momentum



When relative phase at RF2 for unwanted particle (π) is set to be same as at RF1, deflection with 2 RF cavities is canceled. Then, RF2 phase for wanted particle (K or pbar) is different by:

$$\Delta\varphi_w^u = \frac{2\pi f L}{c}\left(\frac{1}{\beta_w} - \frac{1}{\beta_u}\right) \approx \frac{\pi f L}{c}\,\frac{m_w^2 - m_u^2}{p^2c^2}$$

f: frequency
L: distance between RF1 and RF2
β_w, β_u: velocity of wanted/unwanted particle
m_w, m_u: mass of wanted/unwanted particle

⇒ Wanted particle is deflected by $2A\sin\frac{\Delta\varphi_w^u}{2}$

Comparison of Spectrometer Config.

Intensity and Purity

※ decay μ and cloud π are not included.

- Primary proton beam power: 50 kW
- Production target: 50 % loss
- Spill cycle: 4.24 s

	K^- intensity [x10^6/spill] (K^-/π^- ratio)			pbar intensity [x10^6/spill] (pbar/π^- ratio)		
	5.5 GeV/c	7 GeV/c	10 GeV/c	5.5 GeV/c	7 GeV/c	10 GeV/c
Type.I: QDDQQ (slit)	3.6 (1/8.1)	4.8 (1/7.0)	3.4 (1/13)	4.6 (1/6.3)	3.8 (1/6.9)	1.4 (1/16)
Type.II: QQDDQ (central stopper)	2.8 (1/2.4)	3.6 (1/1.8)	2.2 (1/2.3)	4.1 (1/1.6)	3.5 (1/1.9)	1.3 (1/3.8)
Type.II: QQDDQ (slit)	3.8 (1/7.4)	5.1 (1/6.5)	3.7 (1/12)	5.9 (1/6.3)	5.0 (1/6.5)	1.9 (1/15)

- Type.I: QDDQQ
  - small beam size at final focus (3mm$^{\phi}$ in r.m.s.)
  - K/p-tuned mode (slit) only
- Type.II: QQDDQ
  - large beam size at final focus
  - better separation in π-tuned mode (central stopper)
  - higher intensity in K/p-tuned mode (slit)

➡ Optimization is now underway by Prof. Hwang

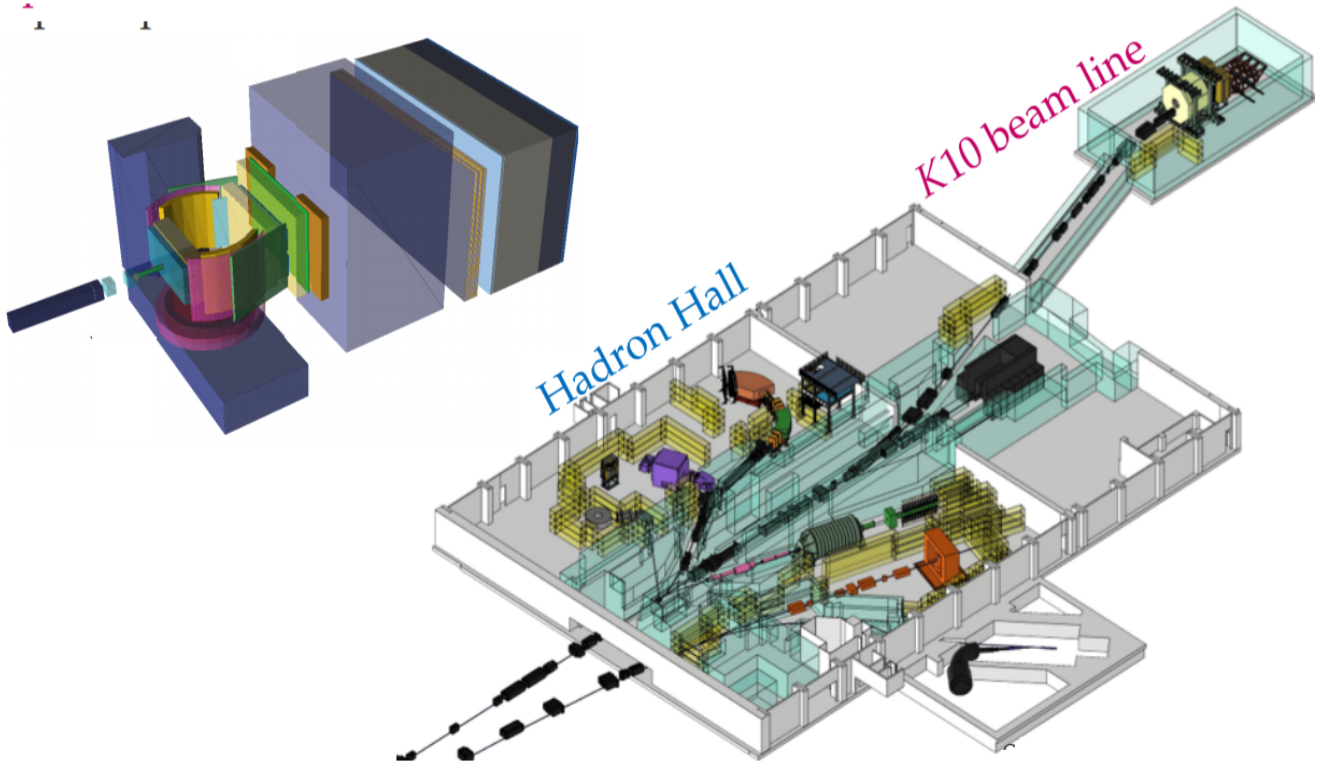
Is K15 possible?

- There is a request to increase the max momentum of K10 to 15 (20) GeV/c.

indico page of this WS+CM

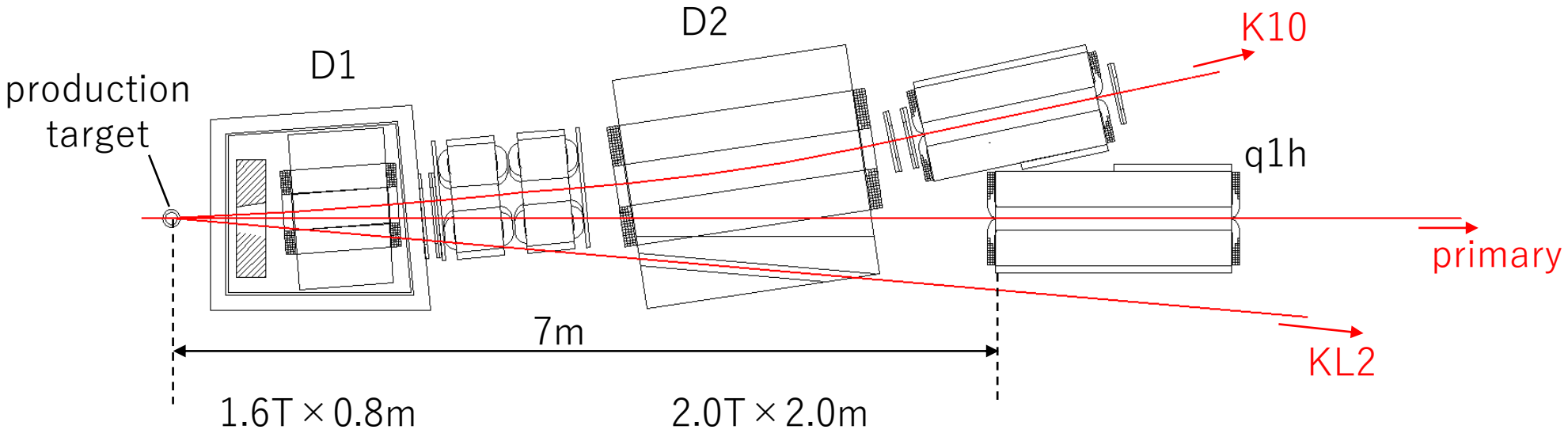
Scientific Objectives & Scope

- Beamline Technology: Up to 10 GeV/c RF-separated secondary beam transport design, focusing on K/pi separation optics with potential extension up to 15 GeV/c.
- Detector Systems: Large-aperture superconducting dipole magnet and high-granularity tracking/ PID subsystems for multi-particle final states.
- Physics Program:
  - Hadron Spectroscopy & Exotic states (multiquark systems, charm/strange baryons).
  - Transition from non-perturbative to perturbative QCD (Confinement mechanism).
  - Time-like Generalized Parton Distributions (GPDs) probing the internal structure of hadrons.



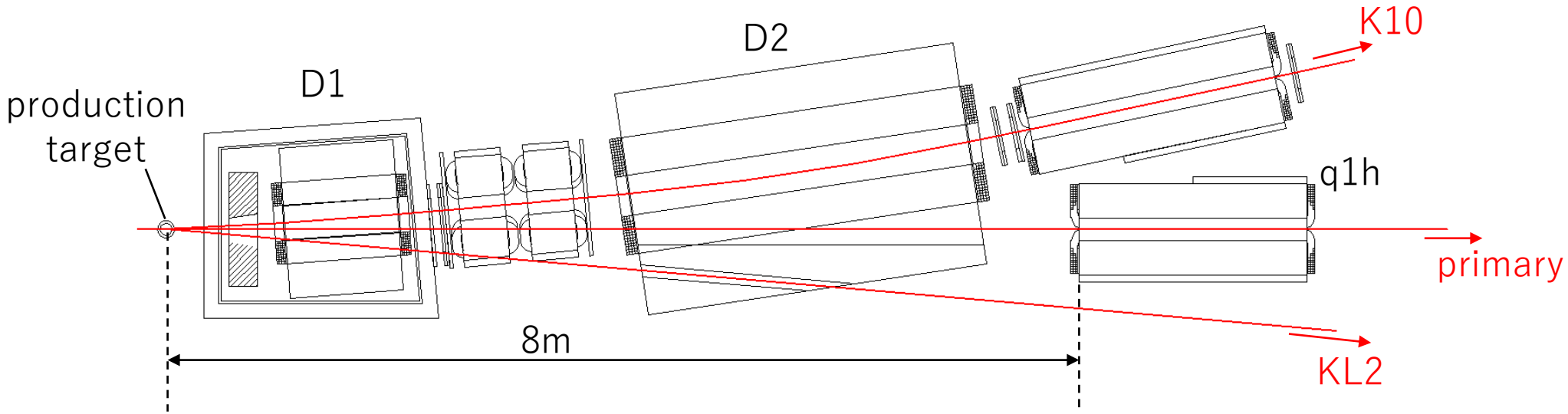
Layout of Front End

K10



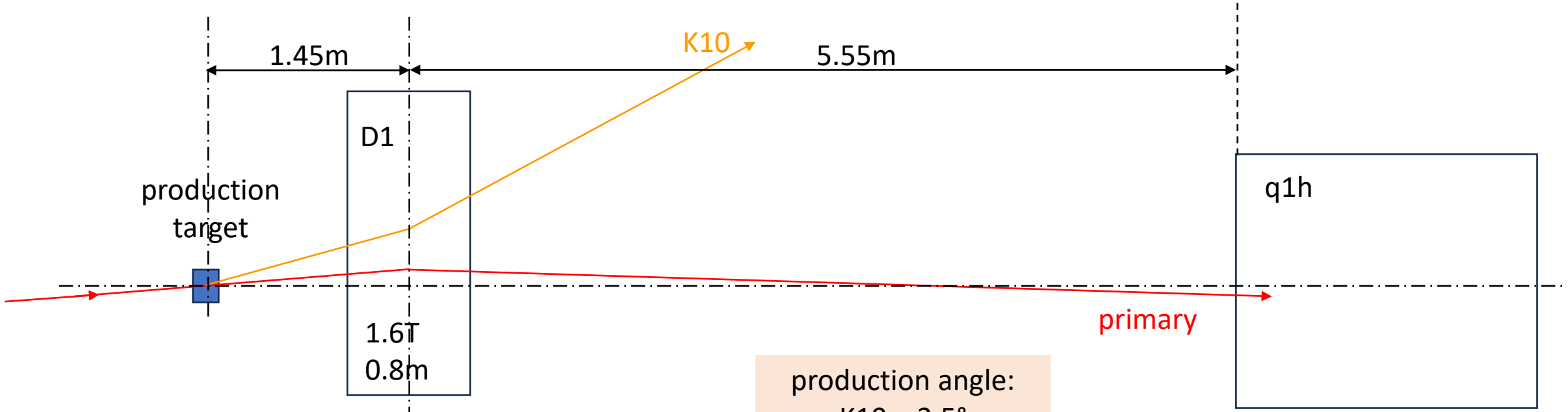
1.9T × 1.0m　　2.0T × 3.0m

K15



10 GeV/c case (current K10 layout)

※ case of negatively charged beams



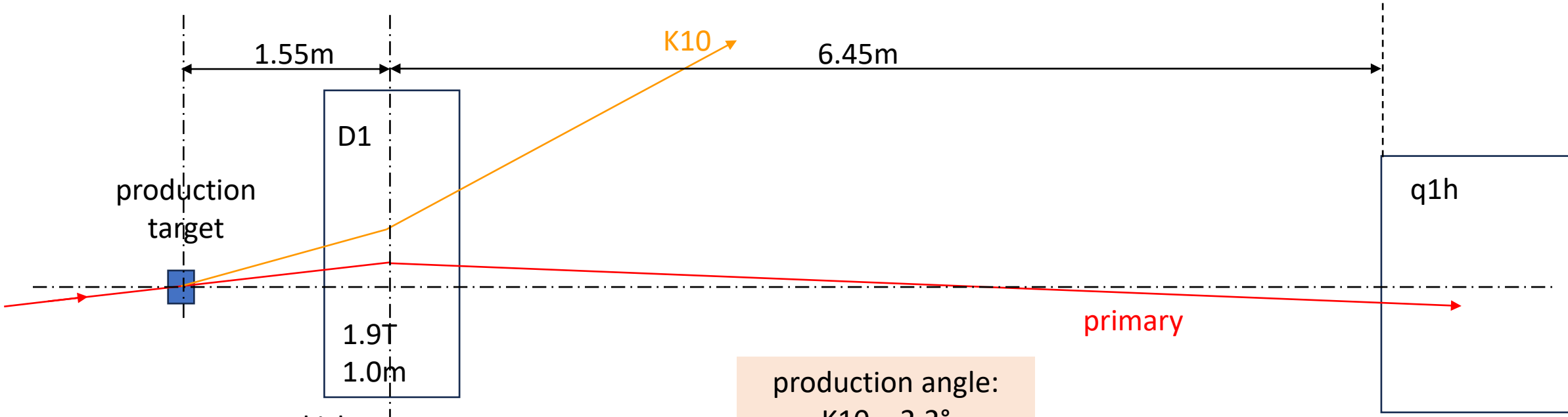
kick:
2.2°(K10)
-0.7°(primary)

production angle:
K10 = 2.5°
(KL2 = 5.5°)

total angle:			
K10	3.0°	5.2°	
primary	0.5°	-0.2°	
primary beam center:	0mm	13mm	-8mm

15 GeV/c case (possible K15 layout)

※ case of negatively charged beams



kick:
2.2°(K10)
-1.1°(primary)

production angle:
K10 = 2.2°
(KL2 = 5.8°)

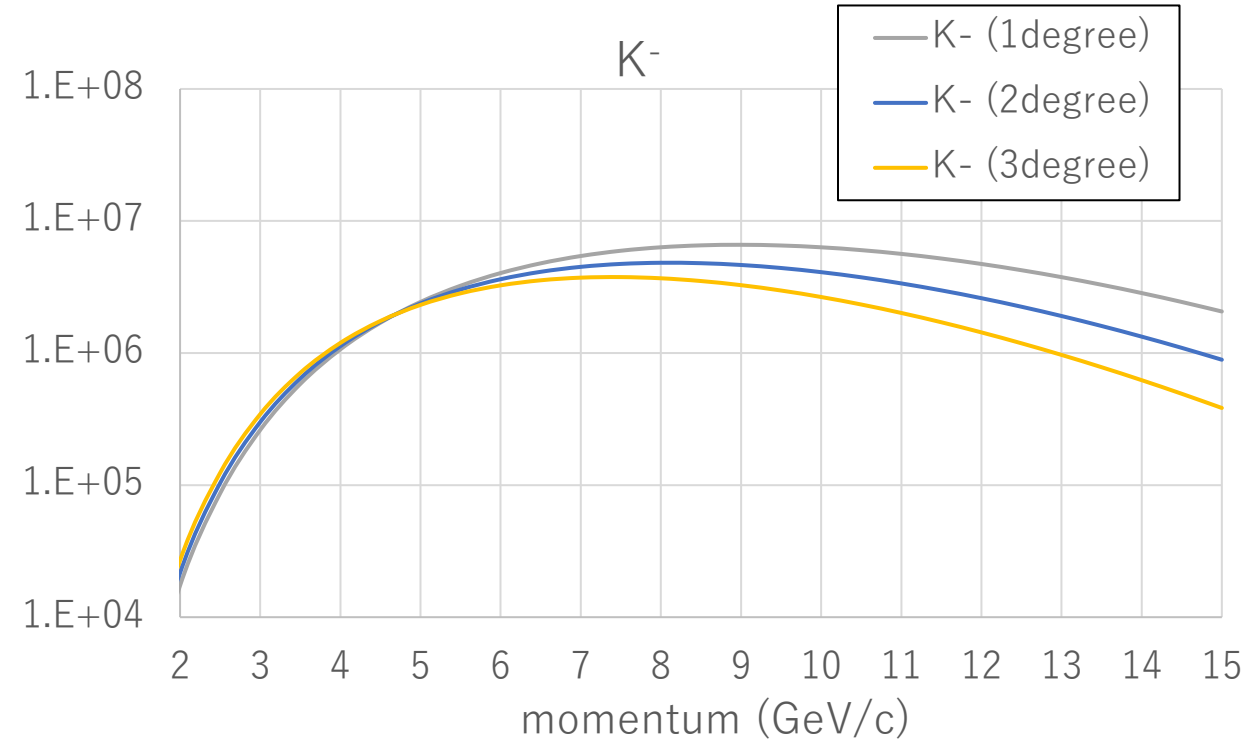
total angle:		
K10	3.0°	5.2°
primary	0.8°	-0.3°
primary beam center:	0mm	22mm

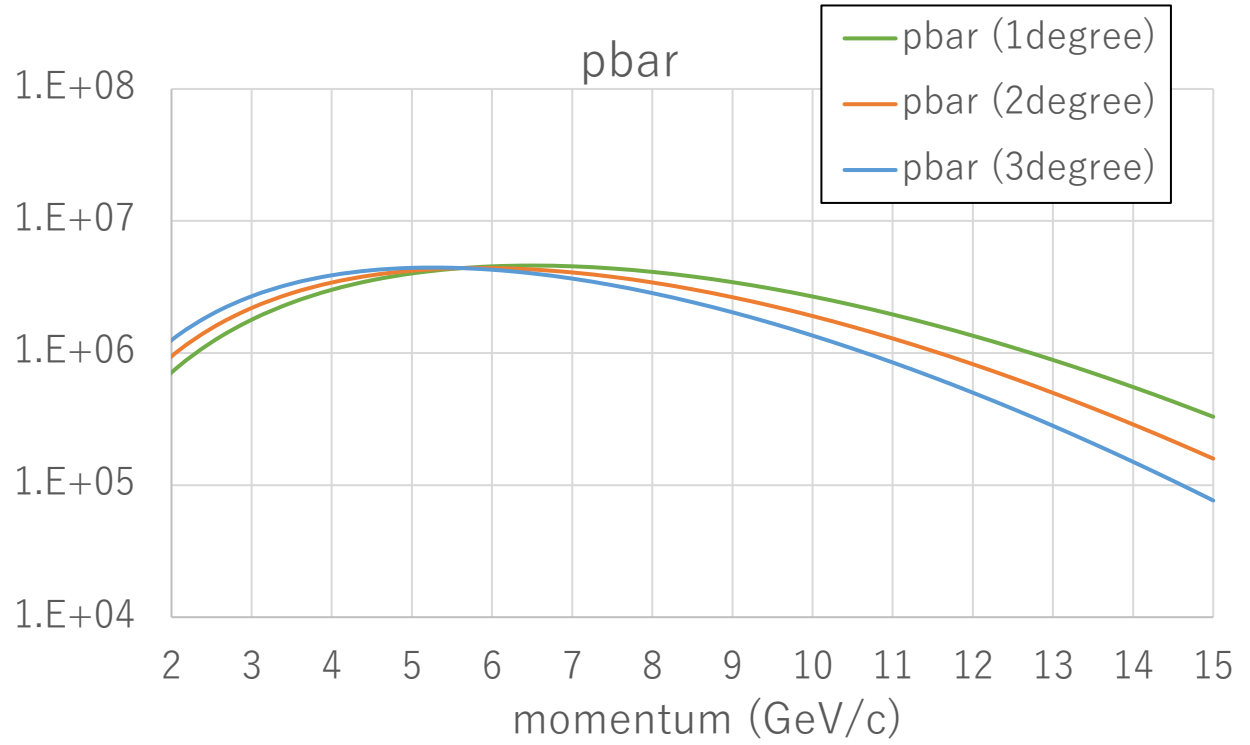
-9mm

Expected Intensity (/spill)

- Primary proton beam power: 50 kW
- Production target: 50 % loss
- Spill cycle: 4.24 s

※ assuming same length and acceptance of beam line





Summary

- K10 beam line was designed to deliver well separated charged secondary beams with a momentum up to 10 GeV/c using a RF separation technique.
- K15 option (very preliminary):
  - The layout of the front-end section seems feasible.
  - K15 needs a larger swinging angle of the primary beam, which affects the production angle of K15 as well as KL2.
  - Expected intensities of 15GeV/c beams are lower than those of 10GeV/c (especially for pbar).
  - Particle separation has not yet been considered.
  - Most significant issue is a cost.

  → We need rich physics programs using p > 10GeV/c that are worth the cost.

This is just a starting point to discuss the maximum momentum of our beam line.