# Possible Hadron Physics with High-Momentum Beam Lines

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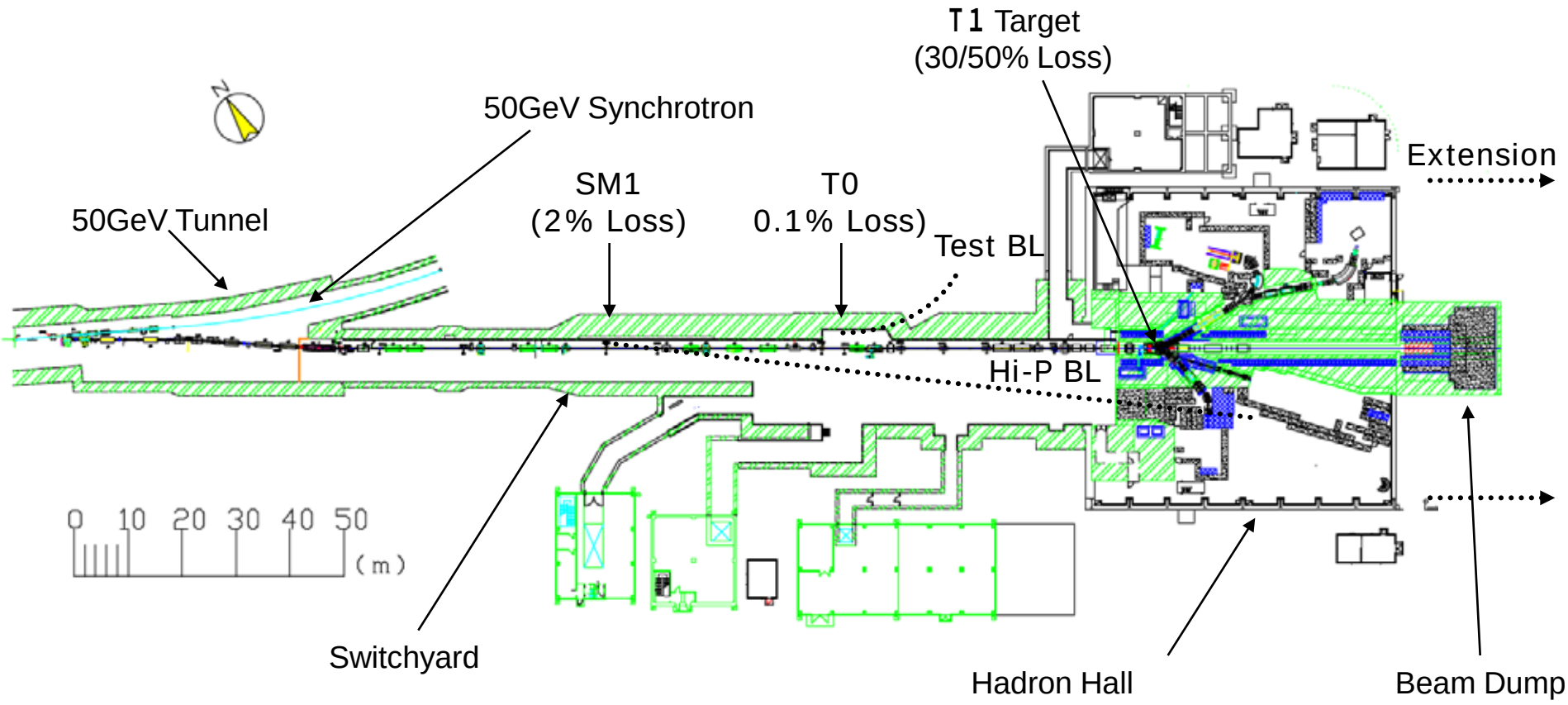
- High-momemtum Beam Line
- Hadron Physics with High-momentum Beam Line
- Separated high-mom beam line at extended HH
- Hadron Physics with Separated High-momentum Beam Line?

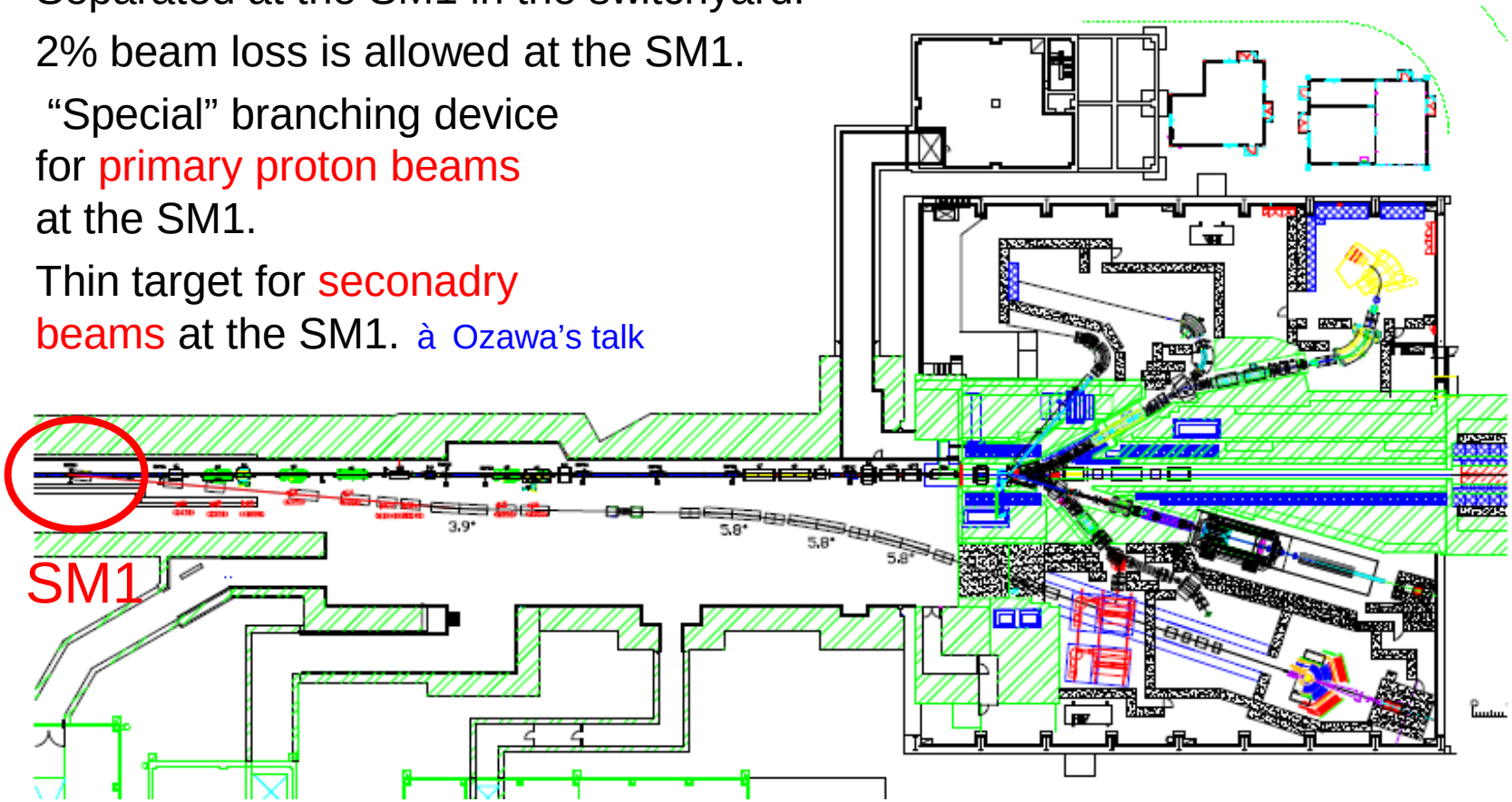
# HIGH MOMENTUM BEAM LINE

# Hadron Experimental Facility (Current Layout)



# High-Momentum Beam Line

- For $10^{10}$ protons/s (E16, vector meson mass), $10^{12}$ protons/s (P04, nucleon structure) , and unseparated p/K.
- Yet to be funded!
- Separated at the SM1 in the switchyard.
- 2% beam loss is allowed at the SM1.
- "Special" branching device for primary proton beams at the SM1.
- Thin target for seconadry beams at the SM1. à Ozawa's talk



# Unseparated Beams (30GeV)

- 30GeV protons + 2% loss copper target. Production angle of 4 degree and (Dp/p)DW= 0.2msr%.

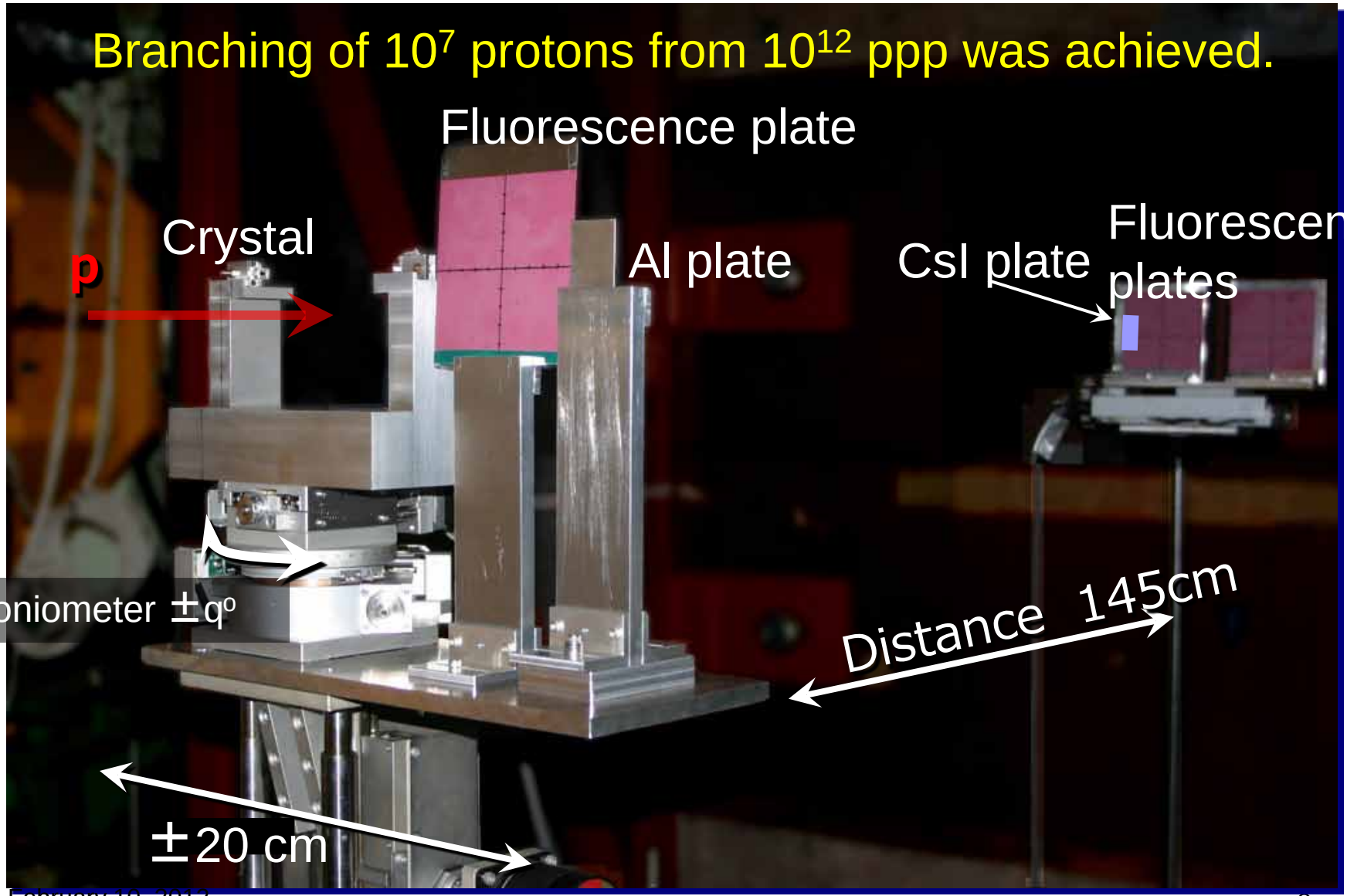
| | Momentum (GeV/c) | ds/dpdW (mb/sr/GeV/c) | Yield at SM1 (per $10^{14}$ protons) | Yield at 120m (per $10^{14}$ protons) |
|---|---|---|---|---|
| $p^+$ | 5 | 1400 | 3.7E7 | 2.4E7 |
| $p^+$ | 10 | 210 | 1.1E7 | 8.9E6 |
| $p^-$ | 5 | 1000 | 2.6E7 | 1.7E7 |
| $p^-$ | 10 | 130 | 6.7E6 | 5.4E6 |
| $K^+$ | 5 | 130 | 3.3E6 | 1.3E5 |
| $K^+$ | 10 | 28 | 1.4E6 | 2.8E5 |
| $K^-$ | 5 | 61 | 1.6E6 | 6.4E4 |
| $K^-$ | 10 | 7.0 | 3.6E5 | 7.2E4 |
| pbar | 5 | 11 | 2.8E5 | 2.8E5 |
| pbar | 10 | 1.1 | 5.7E4 | 5.7E4 |

- Even with 30 GeV protons, enough intensity can be obtained especially for pions!

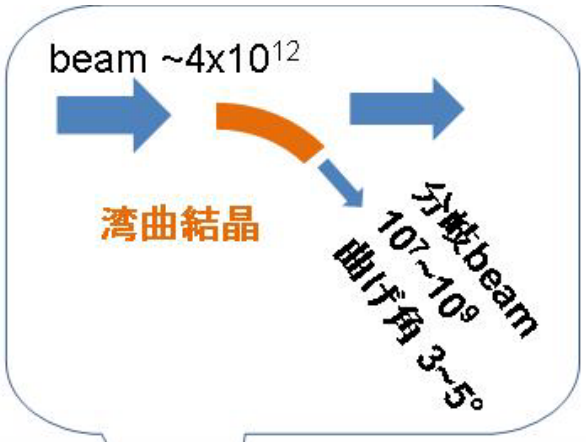
# High Momentum Beam Line

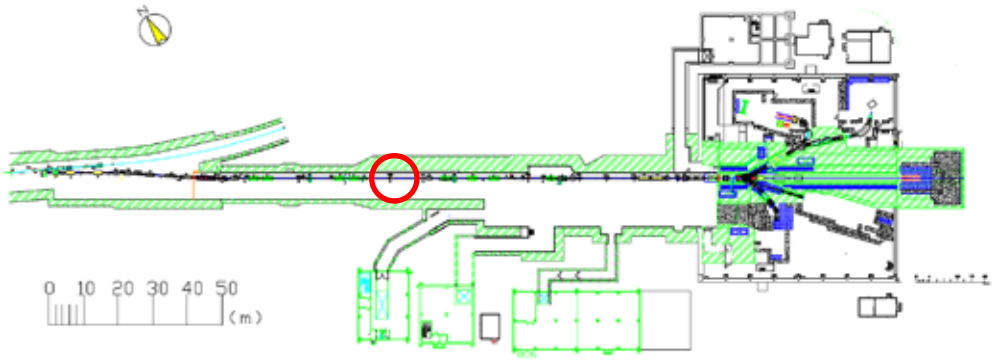
- Main beam: $10^{13}$ – $10^{14}$ protons/spill
  à Branched beam: $10^{9}$ – $10^{10}$ or $10^{12}$ protons/spill
- Conventional method: Electrostatic septum and/or Lambertson magnet
  - Septum: similar to the one used at the slow extraction from the 50-GeV Main Ring.
  - Limited bending power
    - Need 4.85m to bend 30GeV/c beam for 5 deg., even with 1.8T field.
  - Magnet has an issue on radiation and heat.
- Advanced method: Bent Crystal
  - May need only 10mm crystal for 5 deg bending of 30GeV/c beam.
  - Principle was proved at a test experiment at KEK-PS.
  - Need realistic test and design
    - Test experiment with the beam is planned.

# Test Experiment at KEK-PS

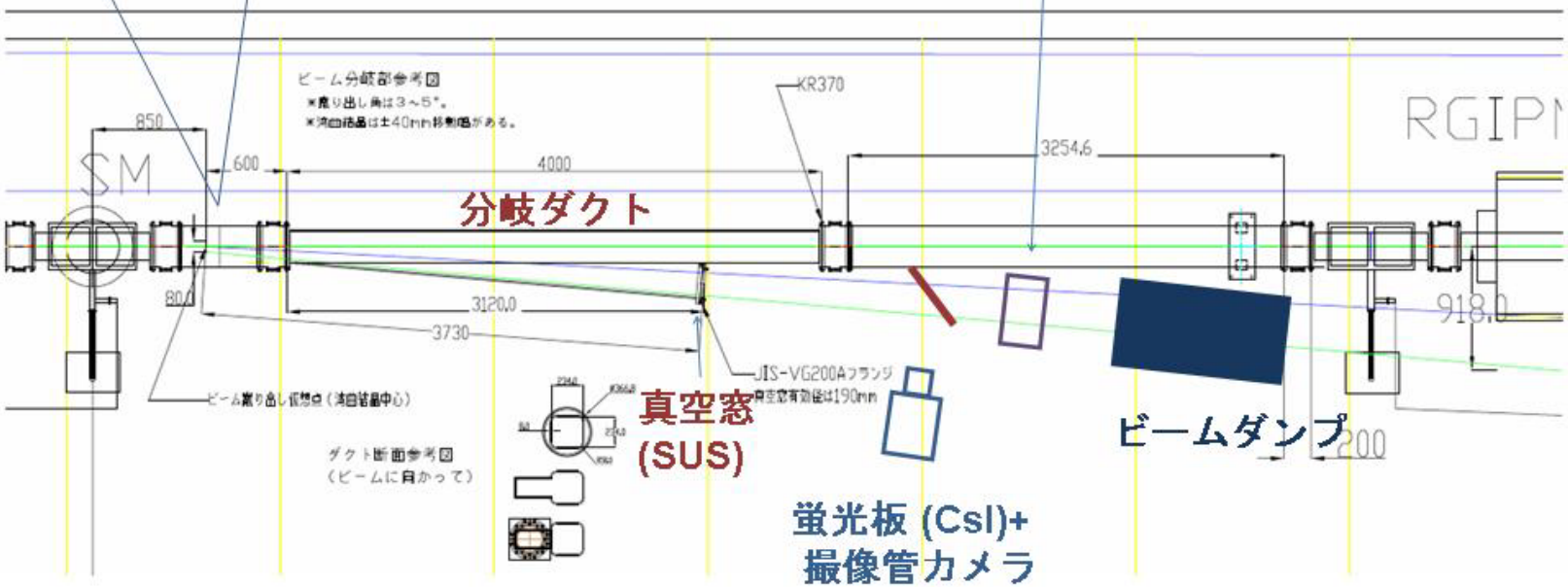


# R&D@J-PARC




イオンチェンバー
(ビームの量)

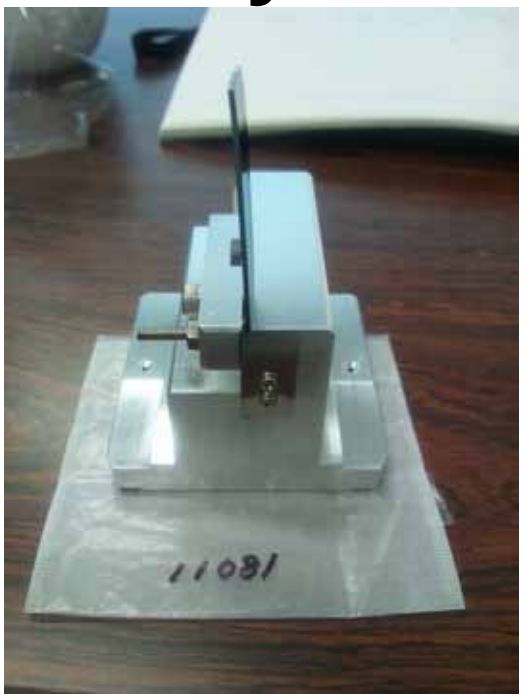



蛍光板 (CsI)+
撮像管カメラ

または、GEMを用いた
profile monitor

# Newly Fabricated Crystals

- Self-support bent crystal is NOT obvious.
- We have tried “plastic bending” of 10mm length and 5 degree bending.
- To be tested by the proton beam at J-PARC!



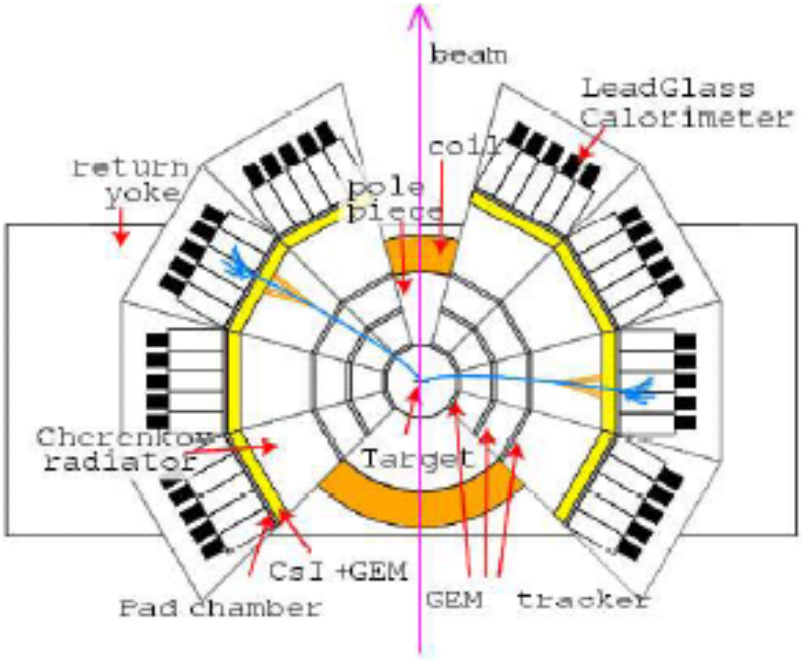

# EXPERIMENTS AT HIGH MOMENTUM BEAM LINE with primary protons

# J-PARC E16: Electron pair spectrometer to explore the chiral symmetry in QCD

**primary proton beam at high momentum beam line**
**+ large acceptance electron spectrometer**

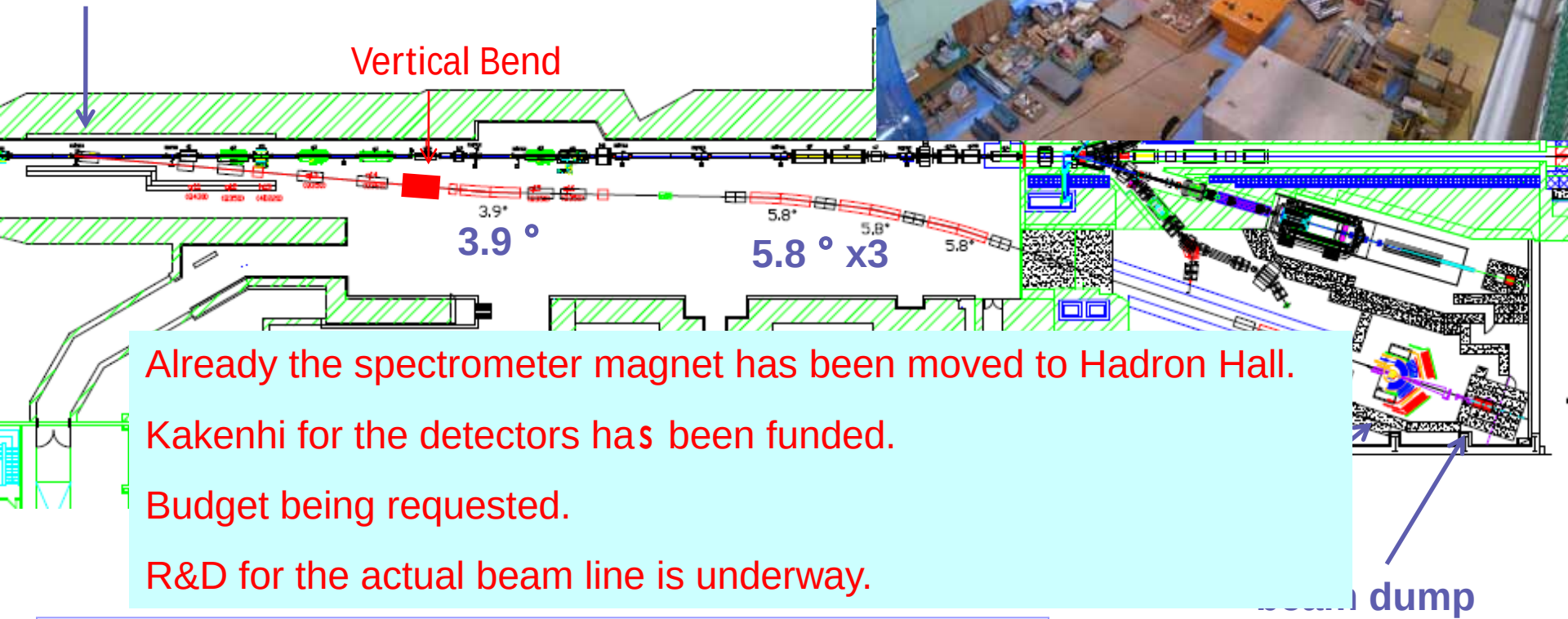
$10^7$ interaction (10 X E325)
$10^{10}$ protons/spill
with 0.1% interaction length target
**à GEM Tracker**
eID : **Gas Cherenkov**
**+ Lead Glass**
**Large Acceptance (5 X E325)**
à **x100 statistics**

**velocity dependence**
**nuclear number dependence (p à Pb)**
**centrality dependence**
à systematic study of mass modification



# Location of E16 : High

**SM1: branched by 5 °**
**2% beam loss is allowed**




Already the spectrometer magnet has been moved to Hadron Hall.

Kakenhi for the detectors has been funded.

Budget being requested.

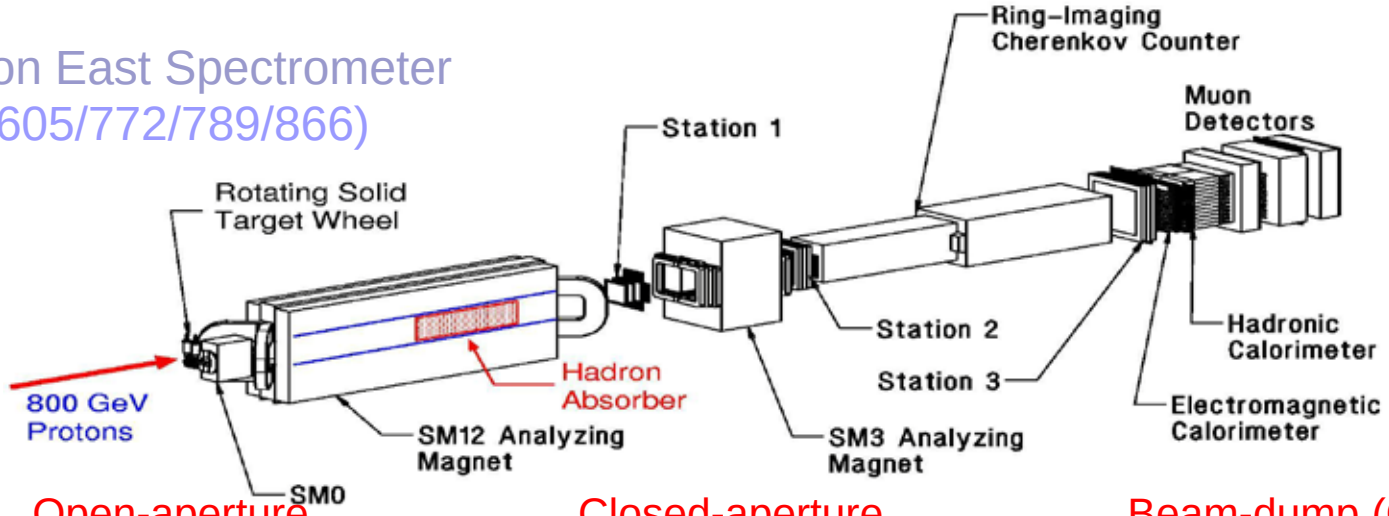
R&D for the actual beam line is underway.

Beam dump and shields are for $10^{10}$ protons/s

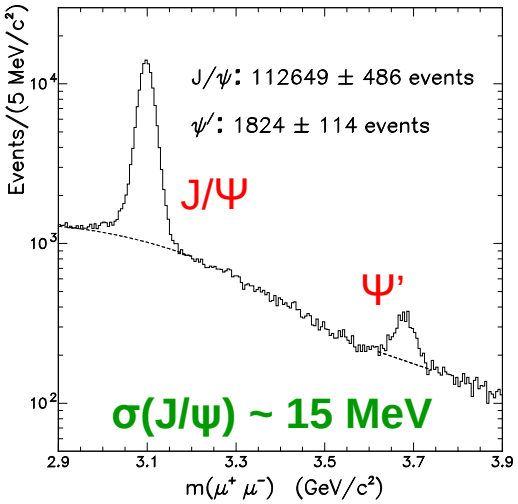
# P04: HIGH MASS DIMUON MEASUREMENT

# Examples of Drell-Yan: Fermilab Experiments

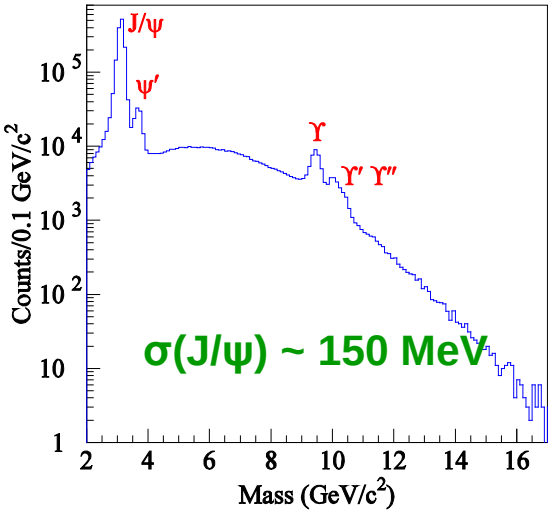
Meson East Spectrometer
(E605/772/789/866)



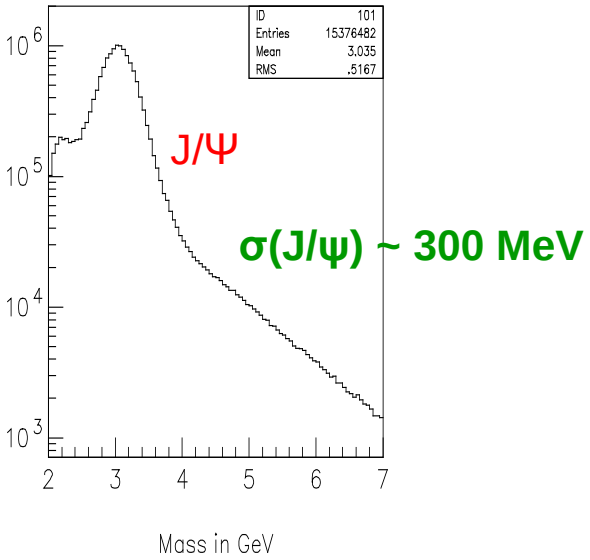

Open-aperture




Closed-aperture

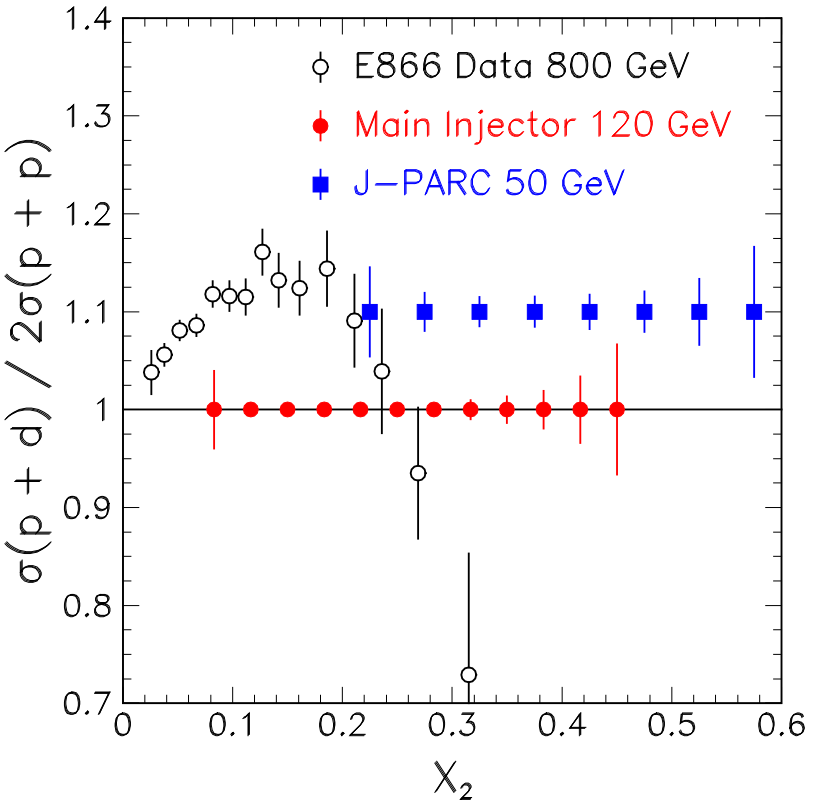



Beam-dump (Cu)



# Antiquarks in nucleons

- dbar/ubar at Large x using 50 GeV Protons.
- J-PARC can measure d-bar/u-bar at larger x.
- Not only the flavor asymmetry for p + p, but also other measurements, such as nuclear dependence, spin observables, etc. can be done.
- Strategy: SeaQuest(E906) at Fermilab until ~2015.



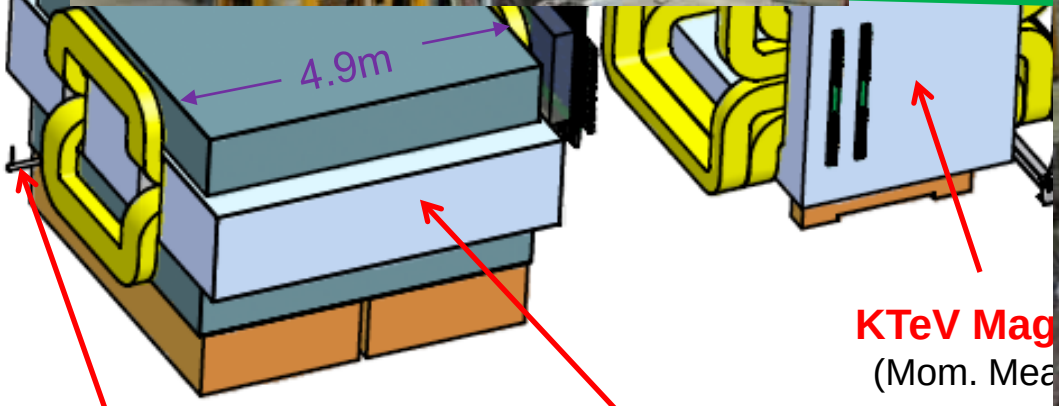

$10^{12}$ protons per spill (3 s)

50-cm long $LH_2$ / $LD_2$ targets

60-day runs for each targets

assuming 50% efficiency

# Drell-Yan Spectrometer for E-906/SeaQuest (25m long)




**Targets**
(liquid $H_2$, $D_2$, and solid targets)

**Solid Iron Magnet**
(focusing magnet, hadron absorber and beam dump)

**KTeV Mag**
(Mom. Mea

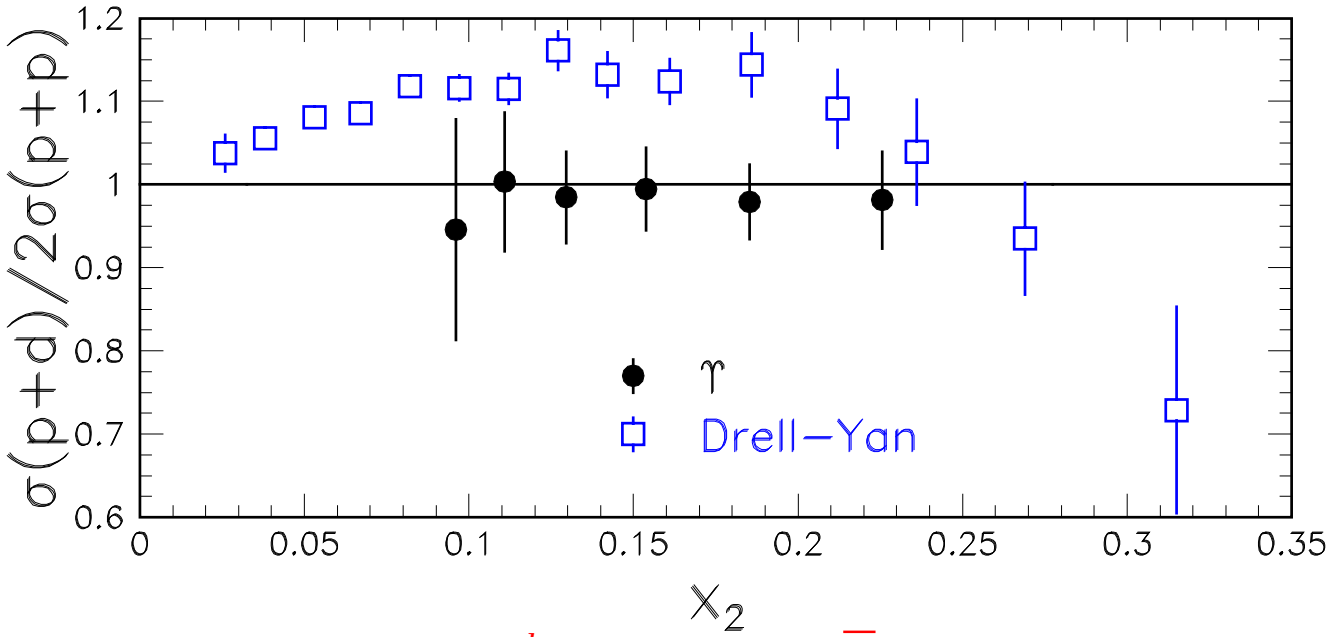
**Station 2**
(hodoscope array, drift chamber track.)

# Strategy

- SeaQuest at Fermilab
  - 2012 – 2015 with 120 GeV protons
  - Polarized beam(/target) after 2015?
    - Work in progress
- Dimuons at J-PARC?
  - Depending on the results from SeaQuest, measurement of dbar/ubar at 50-GeV may be very much interesting.
  - Even with 30 GeV, J/Psi measurement would be worth pursuing.
    - Production mechanism
    - J/Psi interaction with nucleon/nucleus? à Ohnishi's talk

# J/Psi: gg or q-qbar?

E866 data: $\sigma(p+d \to \mu^+\mu^- X)/2\sigma(p+p \to \mu^+\mu^- X)$




Lingyan Zhu et al., PRL, 100 (2008) 062301

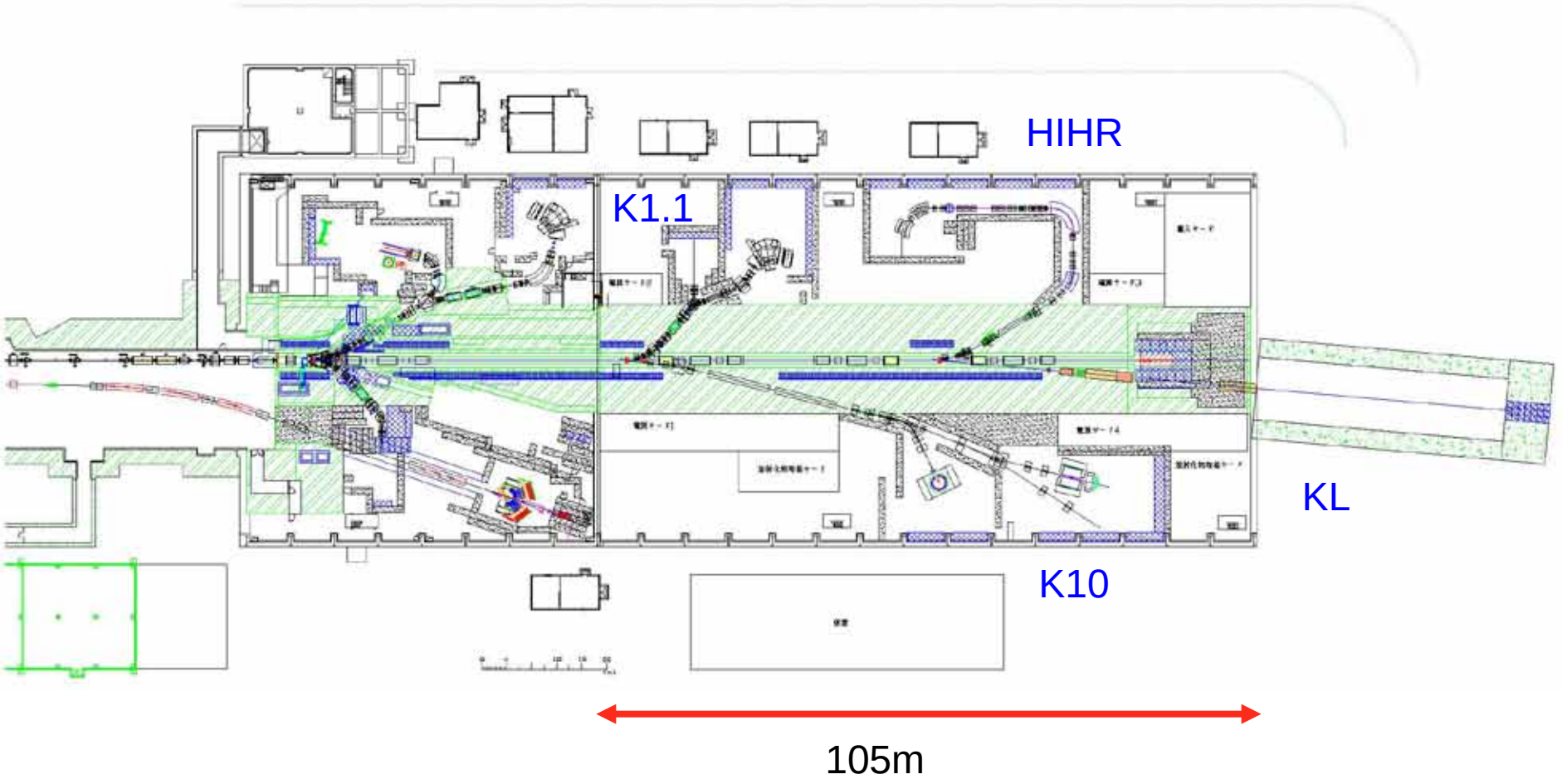
Drell-Yan: $\sigma^{pd}/2\sigma^{pp} \approx [1+\bar{d}(x)/\bar{u}(x)]/2$

$J/\psi, \chi$ : $\sigma^{pd}/2\sigma^{pp} \approx [1+g_n(x)/g_p(x)]/2$

Gluon distributions in proton and neutron are very similar at 800 GeV. At lower energies, J/Psi might be produced by a gluon-gluon fusion. à Azimuthal angle dependence.

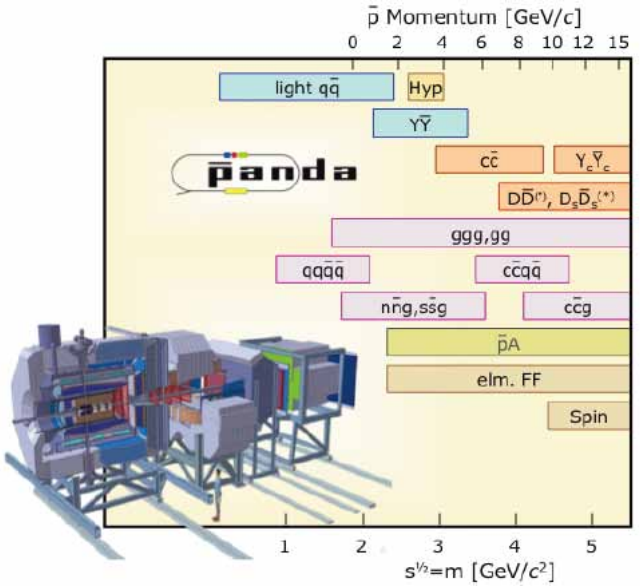
# Hadron Physics with Higher Momentum (Separated) Beams?

# Draft Idea of Hadron Hall Extension in a Private Level



# K10

- Separated beam line up to ~10GeVc.
- RF separator or electrostatic separator (for lower momentum).
- Aims at $10^6$ to ~$10^7$ K's/pbar's /second.
- If one uses 0.35 g/cm$^2$ $H_2$ target (~5cm long), the luminosity would be 2E29 to 2E30 /cm$^2$/sec
  - Cf. PANDA@FAIR: 2E32 /cm$^2$/sec.

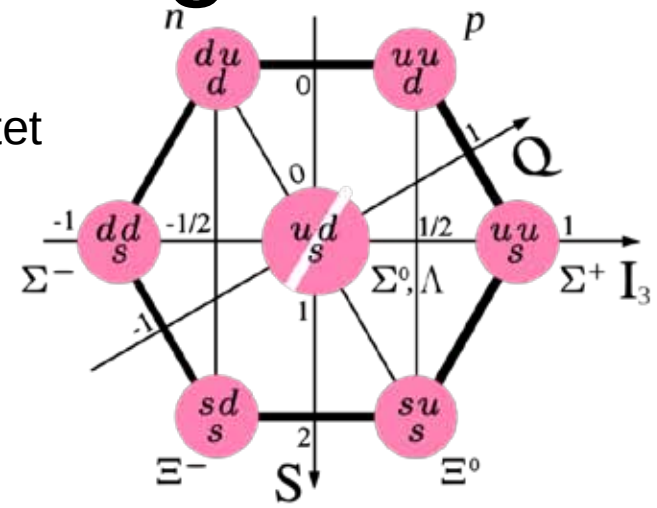


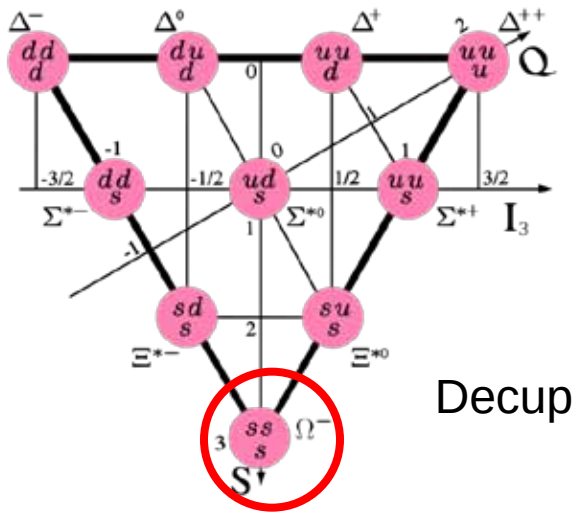
# K10: Possible Physics?

- Baryon spectroscopy with S=-1
  - (pi, K+) reaction
- Baryon spectroscopy with S=- 2
  - (K-, K+) reaction @ p>2 GeV/c
- Baryon spectroscopy with S=-3
  - Ω: (K-, K+K+) @~6 GeV/c
  - Ω by p(pbar, Omega-bar)Omega ??
- Charm in nuclei
  - Charmonium in nucleus?: pbar@3.7 – 6.6 GeV/c
  - Physics with D/Dbar??

# Omega (Hitoshi Takahashi (KEK))

Octet



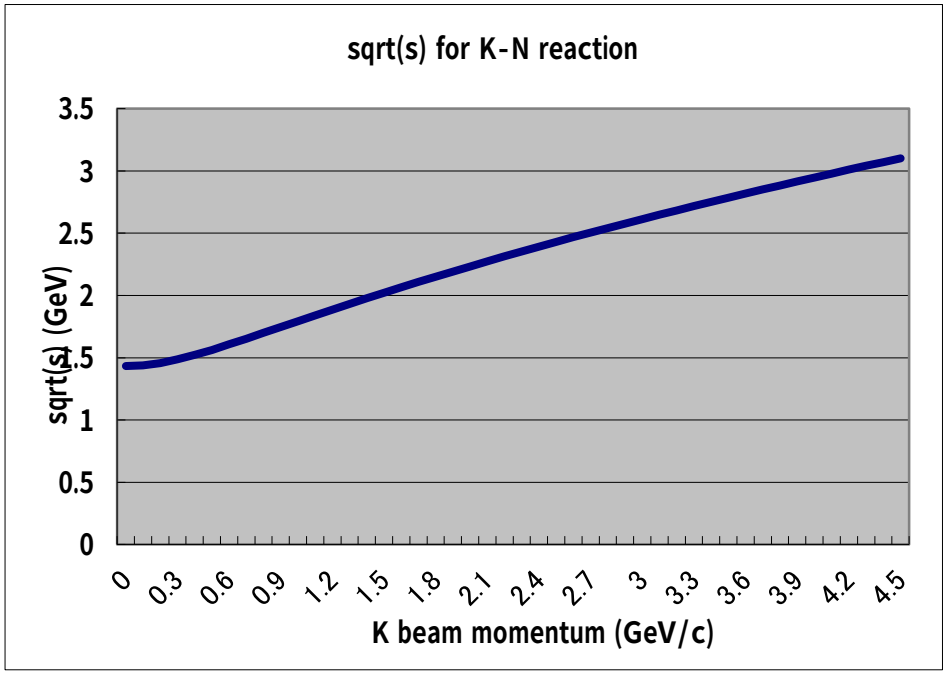

Decuplet

- So far baryon interaction in the $SU(3)_f$ octet has been (and is being) investigated.
- Omega- is the only stable state for the strong interaction in the decuplet.
- Study of the Omega- - nucleon interaction will bring completely new information on the baryon-baryon interaction at the decuplet within the framework of the quark picture.

# Omega (Hitoshi Takahashi (KEK))

- Strategy: step-by-step experiment
  - Get basic information about Omega-N interaction
    - “A” dependence of the Omega- (and Omega* if possible) production
  - Angular distribution and spin/parity of Omega*s are also interesting to be measured.
  - Design experiments with the basic information
    - Omega-nucleus with emulsion
    - Omega-nucleon scattering
    - X-rays from Omega-atom à Omega-A int., electric quadrupole moment of Omega-
- Need 4~6 GeV/c $K^-$ beam

# Eg. p/K beam for excited baryons




- For ~3 GeV, ~4.5 GeV/c p/K beams are necessary, while current max. is 2 GeV/c.
- Unseparated beams (mainly p's) will be available at the high-momentum beam line.

# Ξ Hyperon Engineering

http://hyperon.net/

$\Xi^-$

$\Xi(1530)\ P_{13}$

$\Xi(1690)$

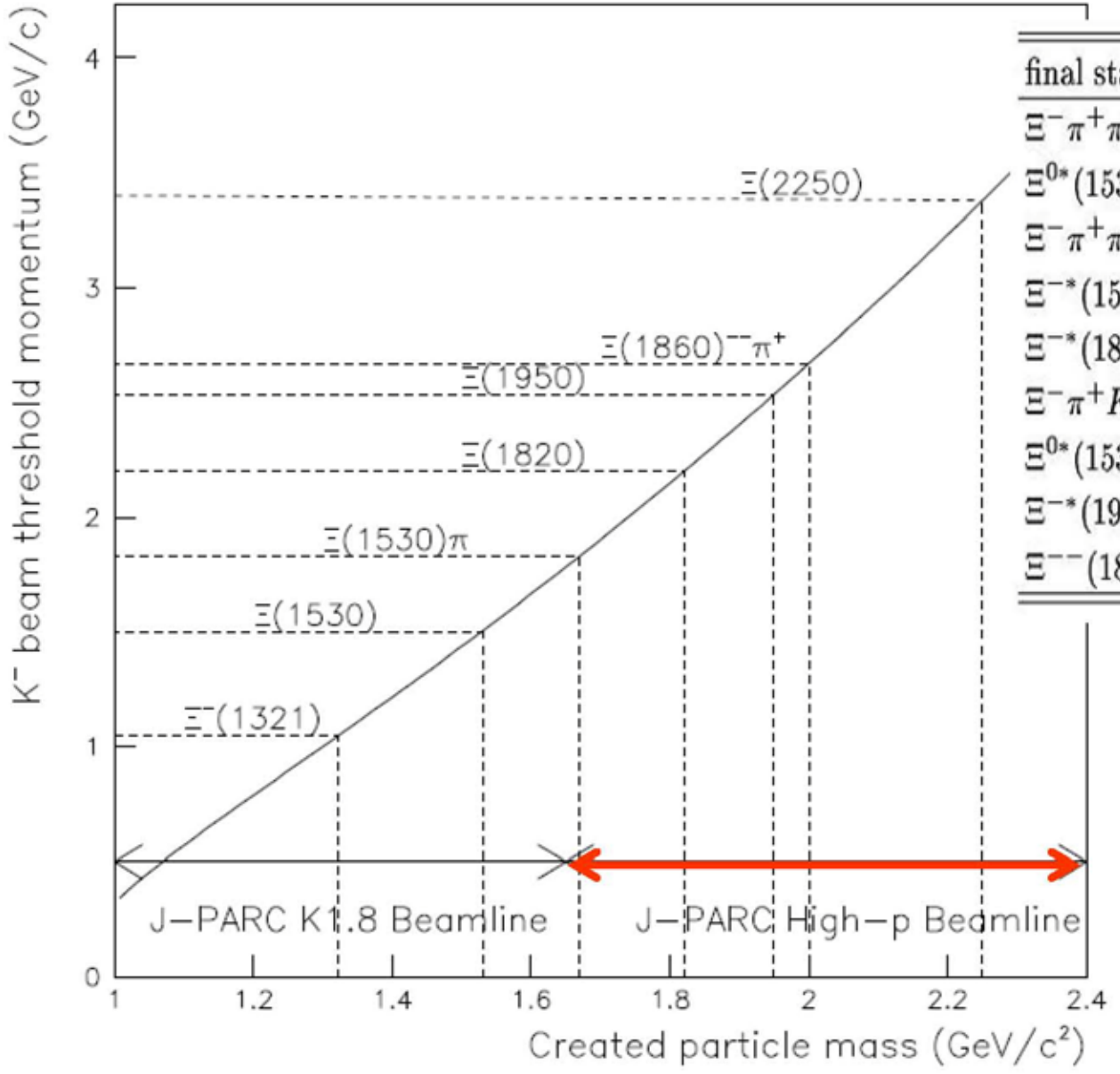
$\Xi(1820)\ D_{13}$

$\Xi(1950)$

$\Xi(2030)$

TABLE I: The status of the Ξ resonances.

| Particle | $L_{2I,2L}$ | Status | $\Xi\pi$ | $\Lambda K$ | $\Sigma K$ | $\Xi(1530)\pi$ | Others |
|---|---|---|---|---|---|---|---|
| Ξ(1318) | $P_{11}$ | **** | | | | | weakly |
| Ξ(1530) | $P_{13}$ | **** | **** | | | | |
| Ξ(1620) | | * | * | | | | |
| Ξ(1690) | | *** | | *** | ** | | |
| Ξ(1820) | $D_{13}$ | *** | ** | *** | ** | ** | |
| Ξ(1950) | | *** | ** | ** | | * | |
| Ξ(2030) | | *** | | ** | *** | | |
| Ξ(2120) | | * | | | | | |
| Ξ(2250) | | ** | | | | | 3-body |
| Ξ(2370) | | ** | | | | | 3-body |
| Ξ(2500) | | * | | * | * | | 3-body |



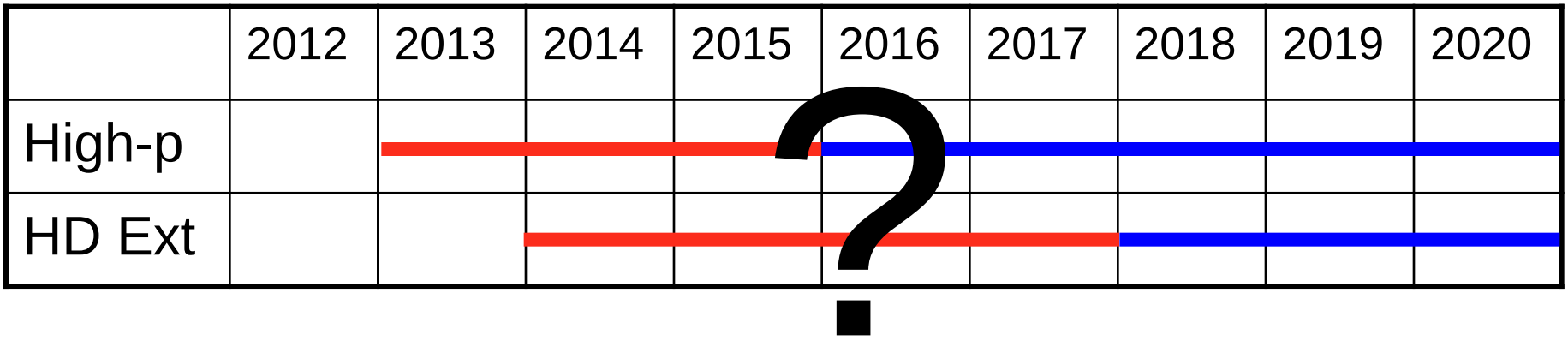

| final state | $p_{\rm th}$(GeV) | $\sigma(\mu$b) |
|---|---|---|
| $\Xi^-\pi^+\pi^-K^+$ | 1.666 | $13^a$, $26^b$, $3^e$ |
| $\Xi^{0*}(1530)\pi^-K^+$ | 1.834 | $11.6^b$, $9^e$ |
| $\Xi^-\pi^+\pi^-\pi^0K^+$ | 1.989 | $25.4^d$ |
| $\Xi^{-*}(1530)\pi^+\pi^-K^+$ | 2.184 | |
| $\Xi^{-*}(1820)K^+$ | 2.206 | $4^a$, $2.5^b$ |
| $\Xi^-\pi^+K^{0*}(892)$ | 2.309 | $10.5^b$, $4^d$ |
| $\Xi^{0*}(1530)K^{0*}(892)$ | 2.494 | $7^c$, $6.5^e$ |
| $\Xi^{-*}(1950)K^+$ | 2.536 | $0.8^b$ |
| $\Xi^{--}(1860)\pi^+K^+$ | 2.668 | |

# K10: Possible Physics?

- Baryon spectroscopy with S=-1
  - (pi, K+) reaction
- Baryon spectroscopy with S=- 2
  - (K-, K+) reaction @ p>2 GeV/c
- Baryon spectroscopy with S=-3
  - Ω: (K-, K+K+) @~6 GeV/c
  - Ω by p(pbar, Omega-bar)Omega ??
- Charm in nuclei
  - Charmonium in nucleus?: pbar@3.7 – 6.6 GeV/c
  - Physics with D/Dbar??

- Study on these possibilities are on going.
- Input from theorists is indispensable!

# (Expected) Time Line



# Summary

- (So-called) High-Momentum Beam Line can provide $10^{10}$ to $10^{12}$/sec primary protons and also unseparated secondary beams.
  - Device R&D is being done, and we expect the beam line would be completed in a few years.
  - The first experiment at the High-p is E16 (modification of phi inside nucleus).
  - Dimuon spectrometer may present much opportunity in hadron physics.
- Separated High-Momentum Beam Line is planned at the extended Hadron Hall.
  - Omega-.
  - Baryon spectroscopy with K- and pbar beams.
  - More to be discussed with theorists.