J-PARC高運動量ビームラインと関連する実験

Shinya Sawada (KEK)

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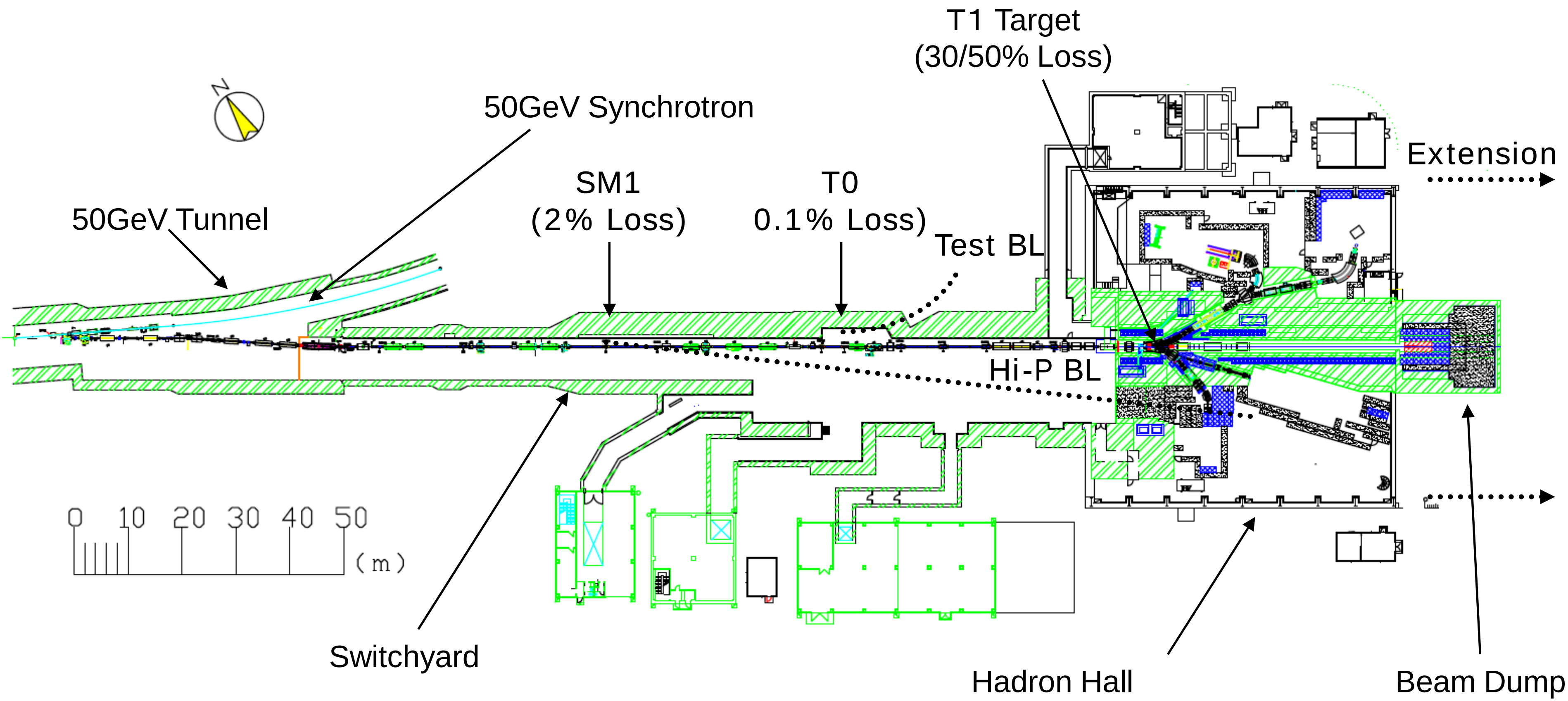
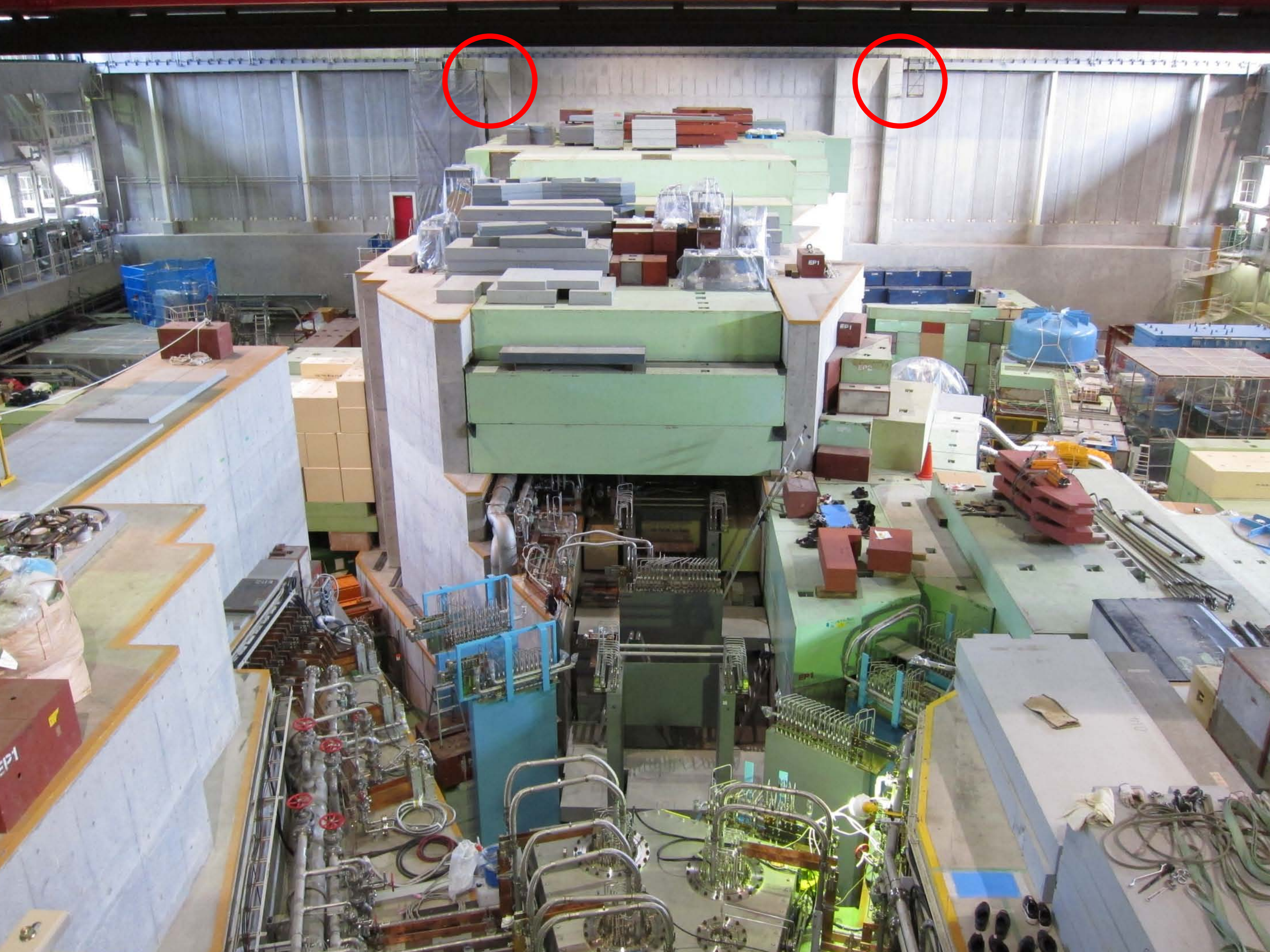
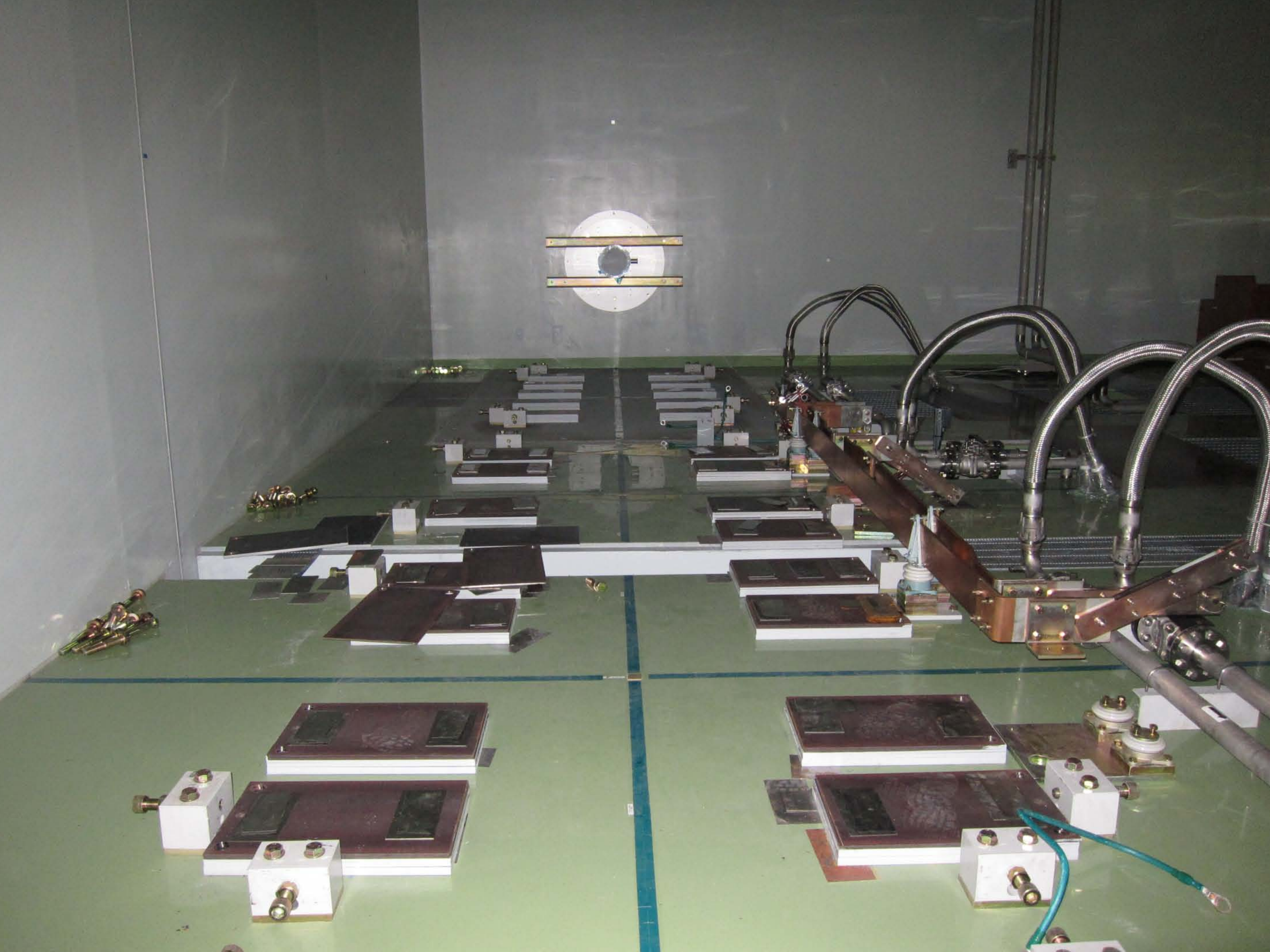
- High-momemtum Beamline
- Hadron Spectroscopy with Separated High-momentum Beamline?
  - Possibility of πN, KN, and pbarN reaction experiments for higher masses at Hadron Hall

Hadron Experimental Facility (Current Layout)




EP1
EP1
EP2
EP1


NEC TOKIN

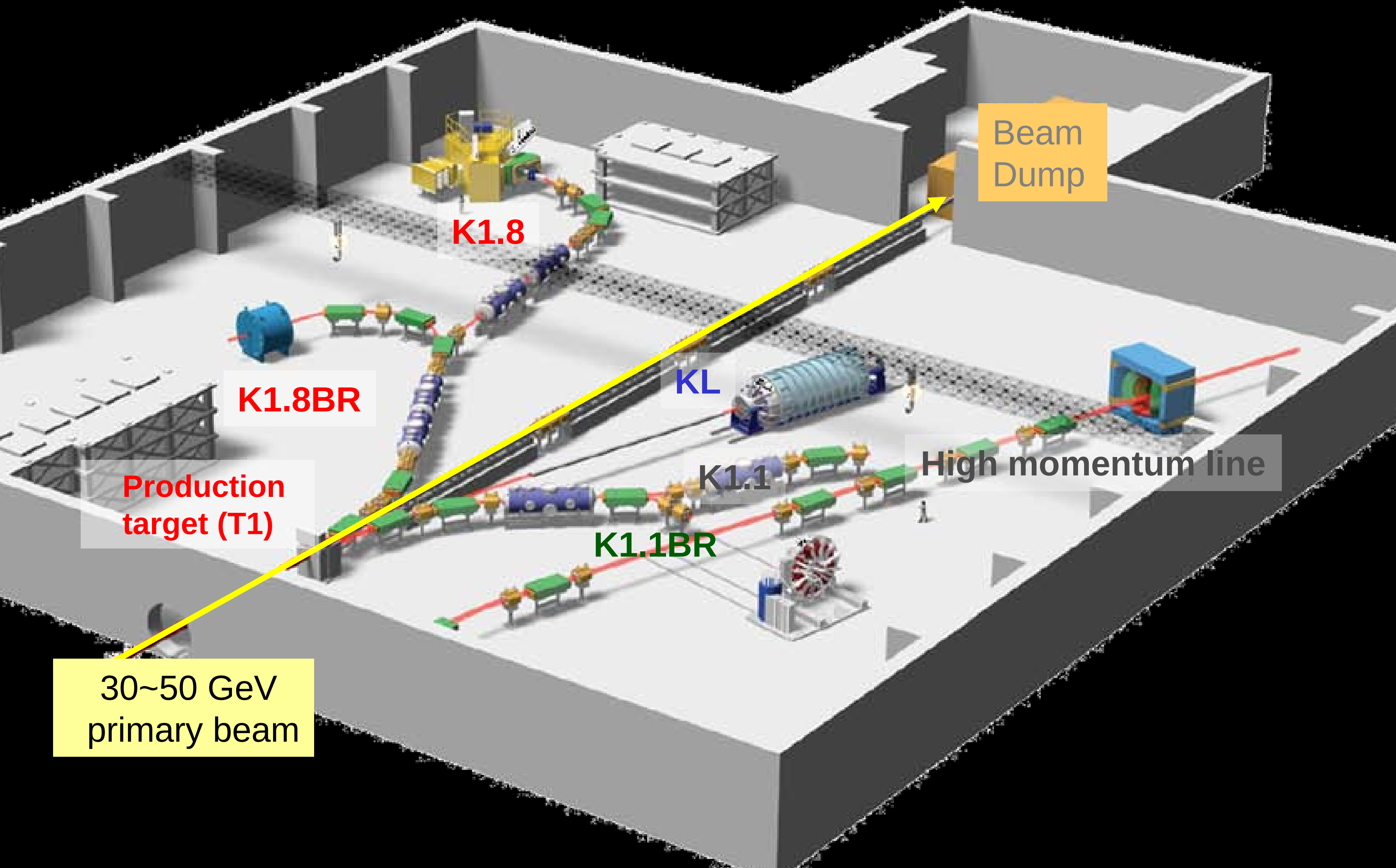


Summary of Damage to Hadron

- Buildings
  - Damages to Hadron Hall building have been or are being repaired.
    - The bolts for the side beams at the east wall are broken.
  - Some cave-ins will be repaired later.
- Cooling water is tentatively recovered.
- Magnets, vacuum, …
  - Magnets themselves seem healthy. A few supports were broken at the experimental areas.
  - Need realignment. Several mm displacement (and sinking) have already been observed. This is due to the displacement (and sinking) of the buildings.
  - Vacuum needs replacements of some elements.
  - Major problem has not been observed for the beam dump.
  - Reconstruction/relocation of shielding with blocks need much time.
- We try to recover the primary beam line by this fall, and ready to accept the beam by the end of the year.

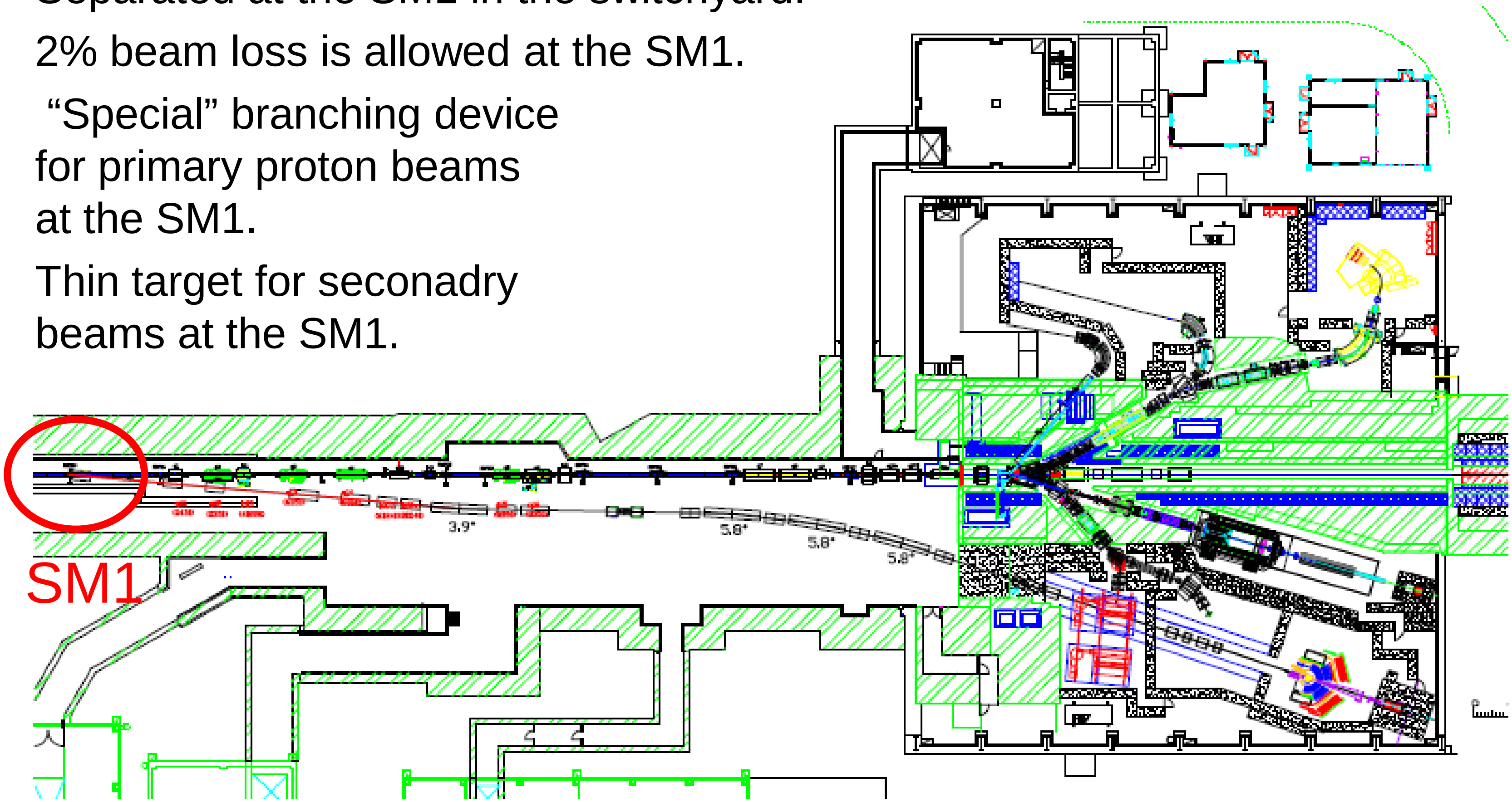
experiments in Hadron Hall

Slide By
H.Tamura

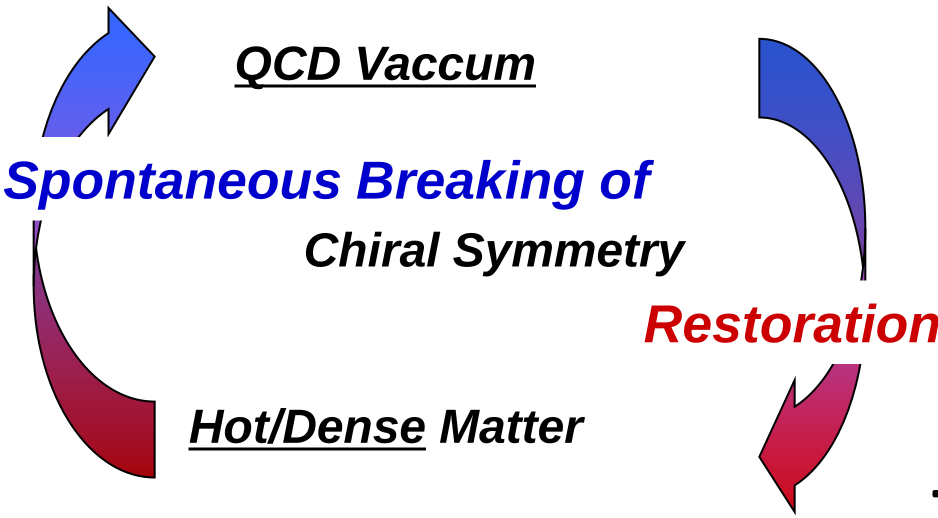


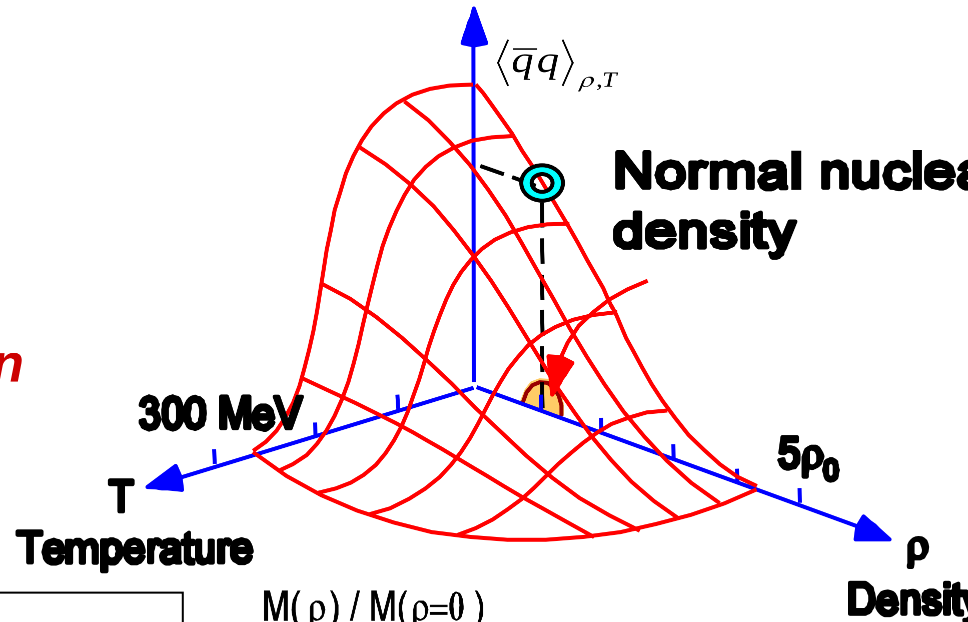
High-Momentum Beam Line

- For 10^{10} protons/s (E16, vector meson mass), 10^{12} protons/s (P04, nucleon structure) , and unseparated π/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.



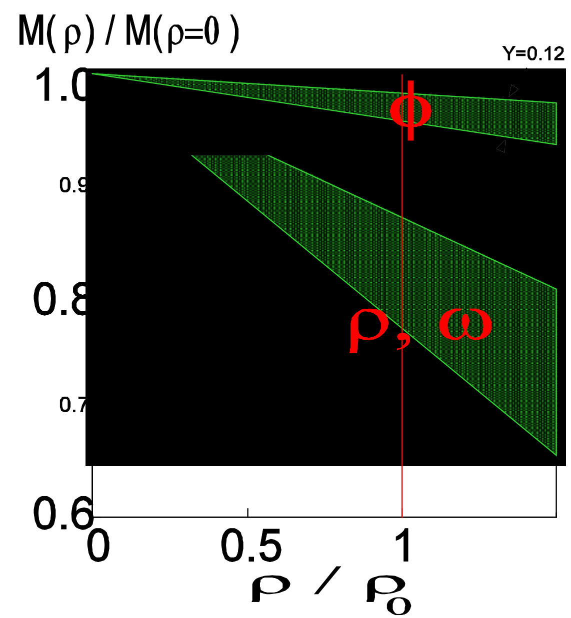
Mass modification of vector meson



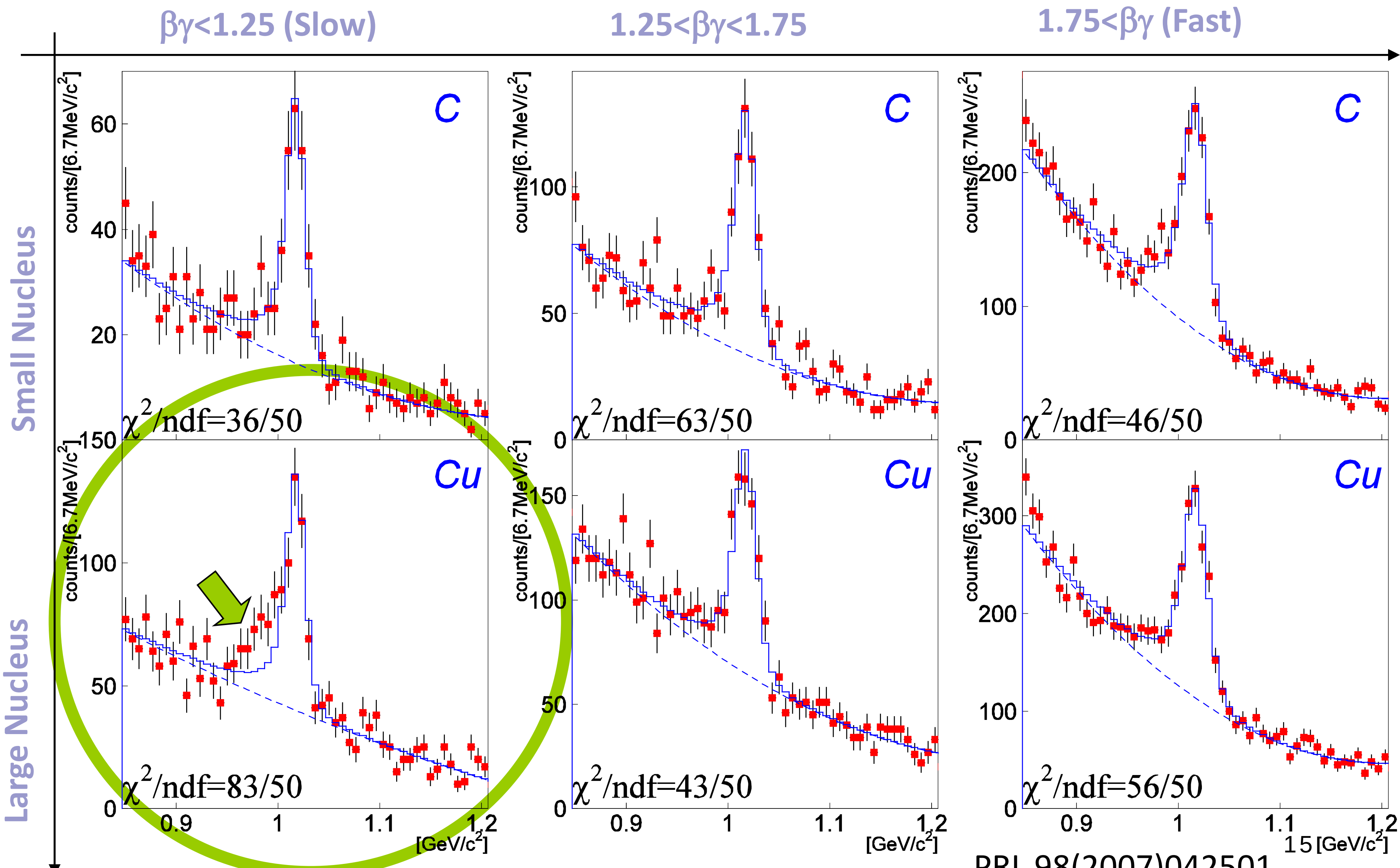


Vector meson mass
at normal nuclear density

$m^*/m=1-k\rho/\rho_0$
(Hatsuda&Lee PRC46(92)R34)
ρ/ω : **Δm = 130 MeV at ρ_0**
ϕ : **Δm = 20~40 MeV at ρ_0**



E16: Results of a previous experiment (KEK-PS E325): Invariant mass spectra of $\phi \rightarrow e^+e^-$

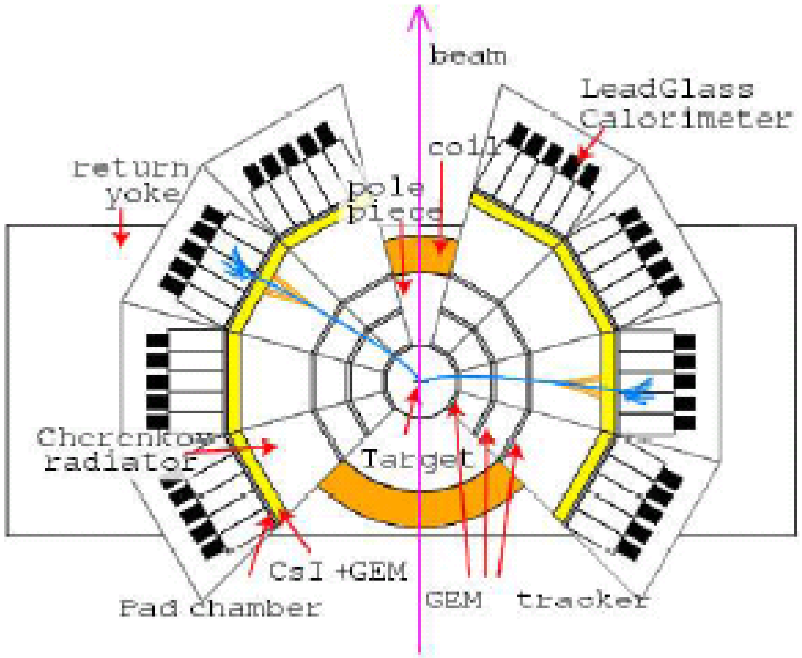


PRL 98(2007)042501

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

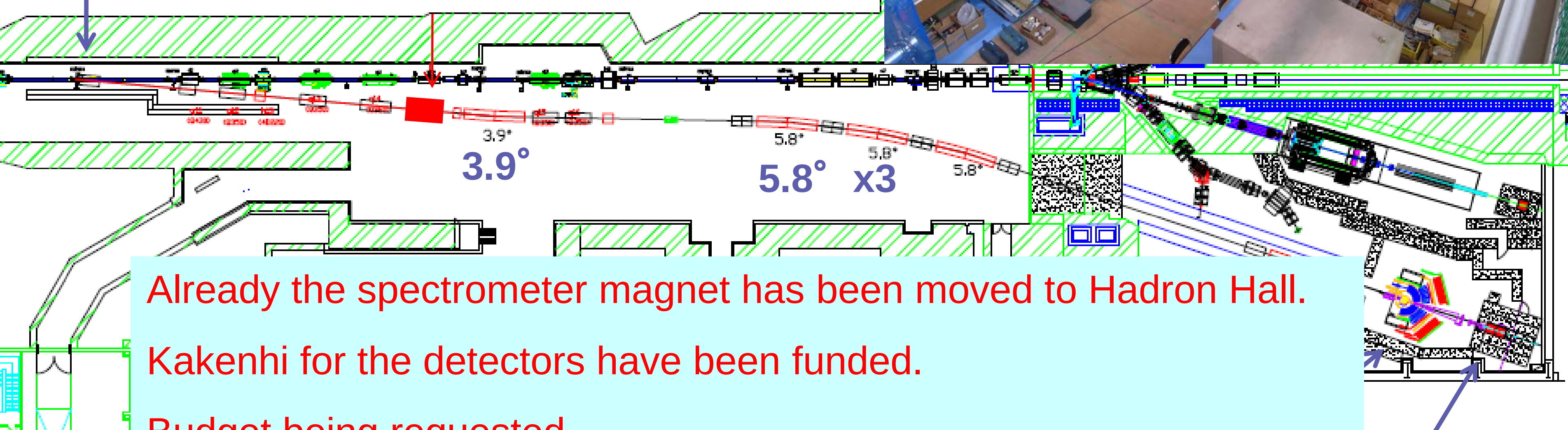
10^7 interaction (10 X E325)
10^{10} protons/spill
with 0.1% interaction length target
→ **GEM Tracker**
eID : **Gas Cherenkov**
+ Lead Glass
Large Acceptance (5 X E325)
→ **x100 statistics**



velocity dependence
nuclear number dependence (p → Pb)
centrality dependence
→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 have been funded.

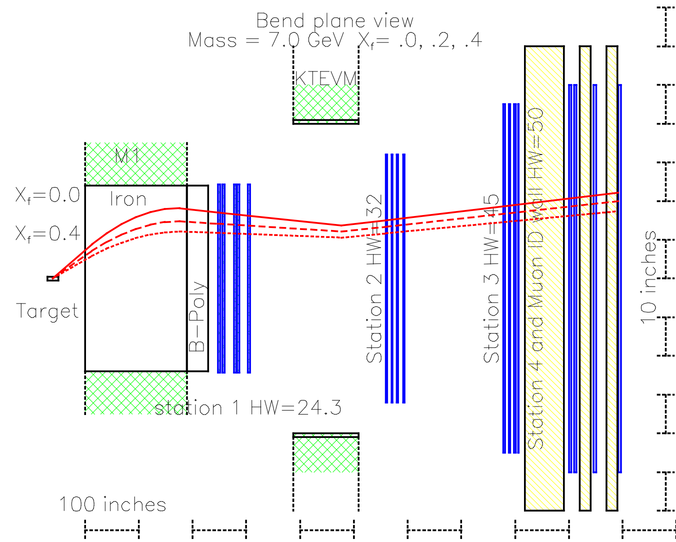
Budget being requested.

R&D for the actual beam line is underway.

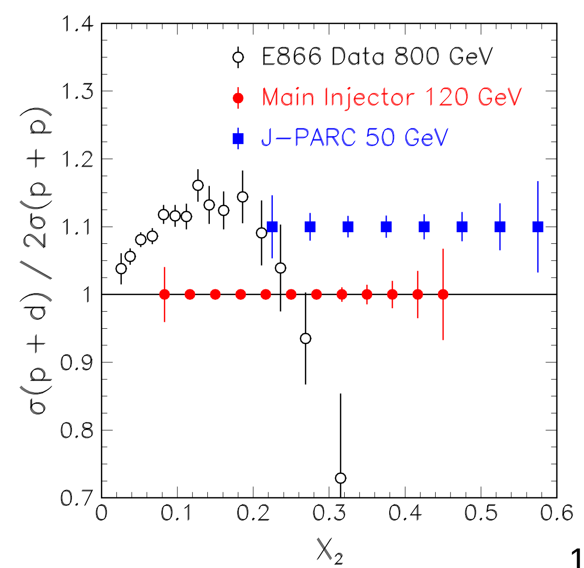
Beam dump and shields are for 10^{10} protons/s

P04: High mass dimuon measurement

- dimuons from p+p, p+d, p+A
- dbar/ubar asymmetry at large x with Drell-Yan process



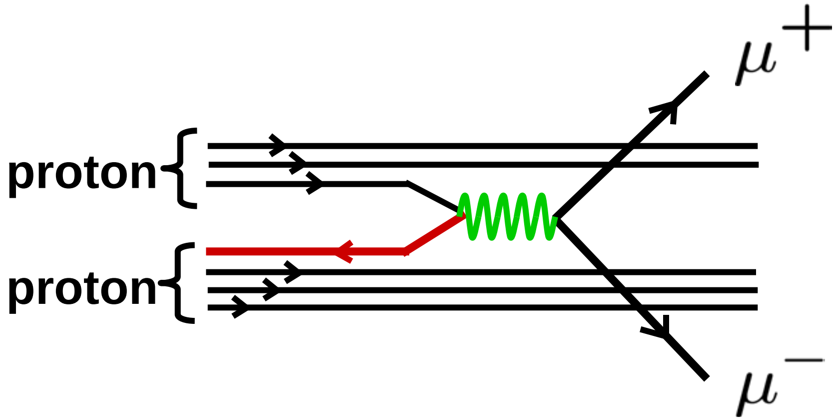
- J-PARC can measure d-bar/u-bar at larger x.

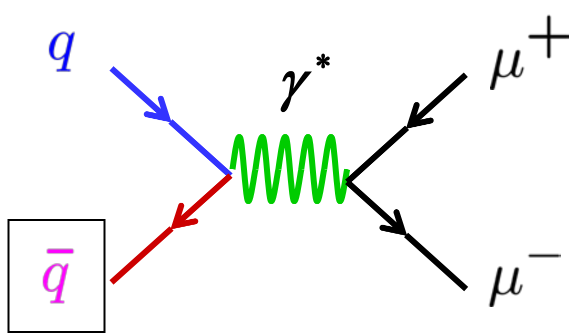


- Experiment at Fermilab (=E906) at 120GeV is first.

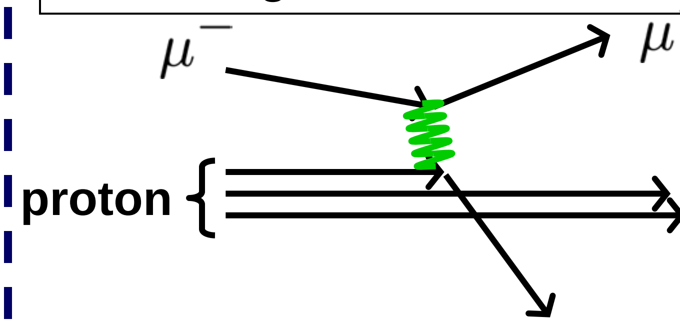
Drell-Yan Process

Drell-Yan process with p-p scattering

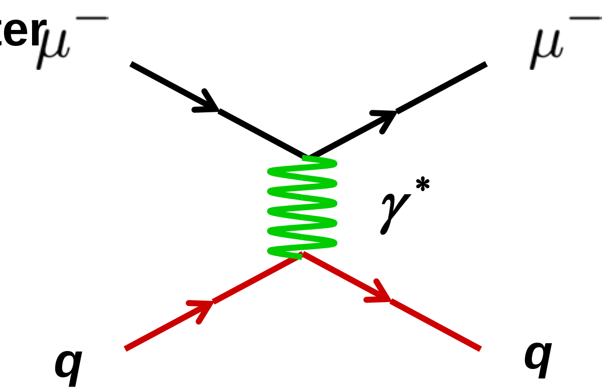




Muon-proton deep inelastic scattering



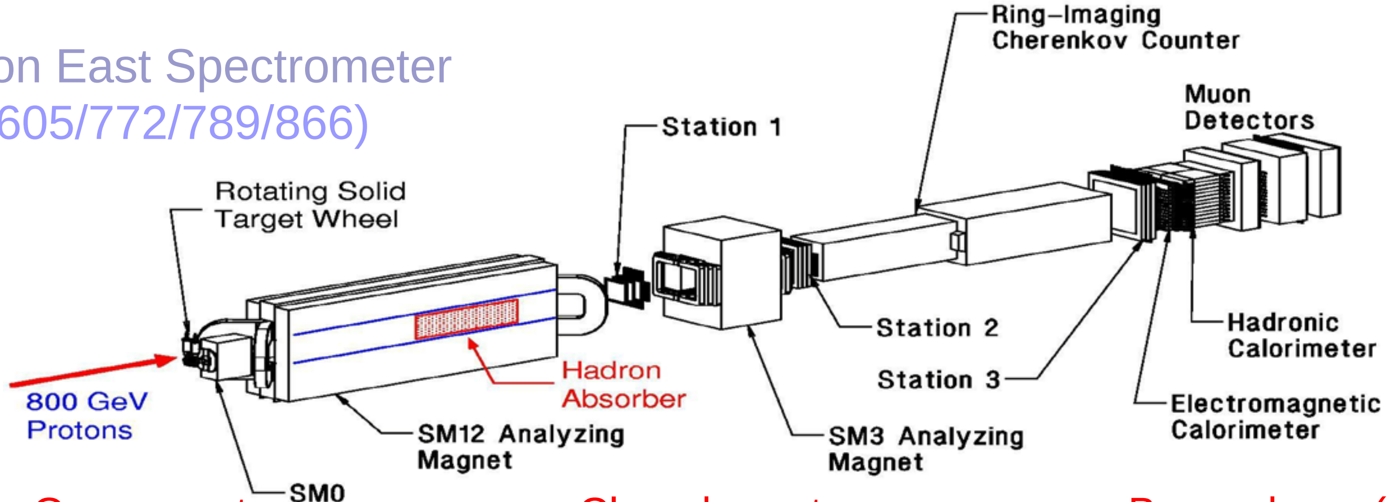
Lepton scattering is the best probe for quak distribution inside matter



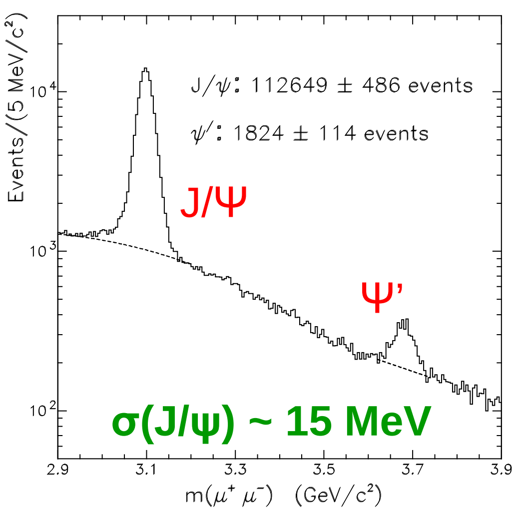
Drell-Yan process is the anti-quark factory: the best probe for anti-quark distcibution inside matter.

Examples of Drell-Yan: Fermilab Experiments

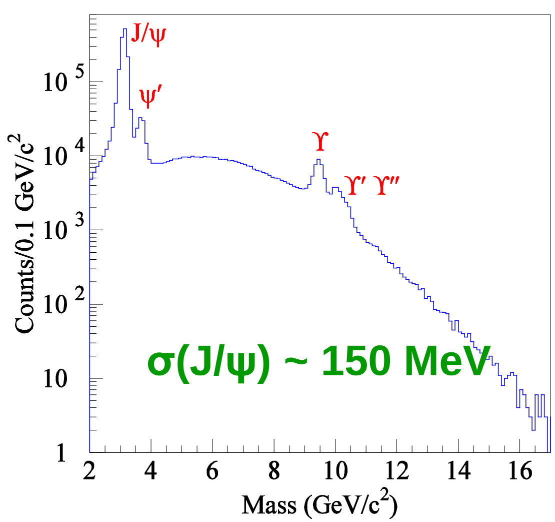
Meson East Spectrometer
(E605/772/789/866)



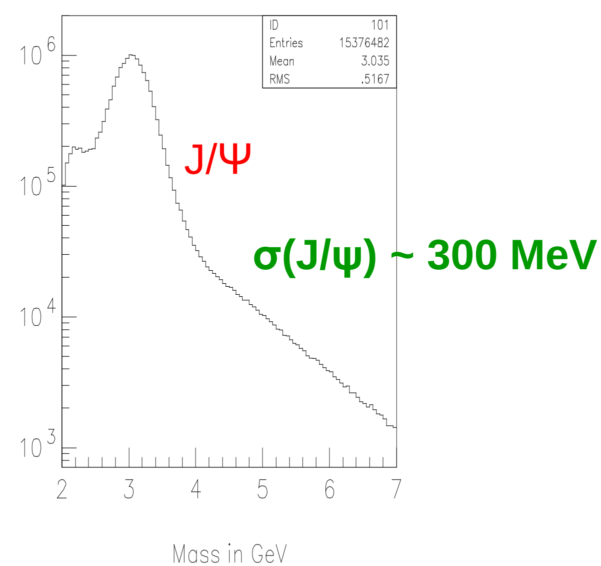
Open-aperture



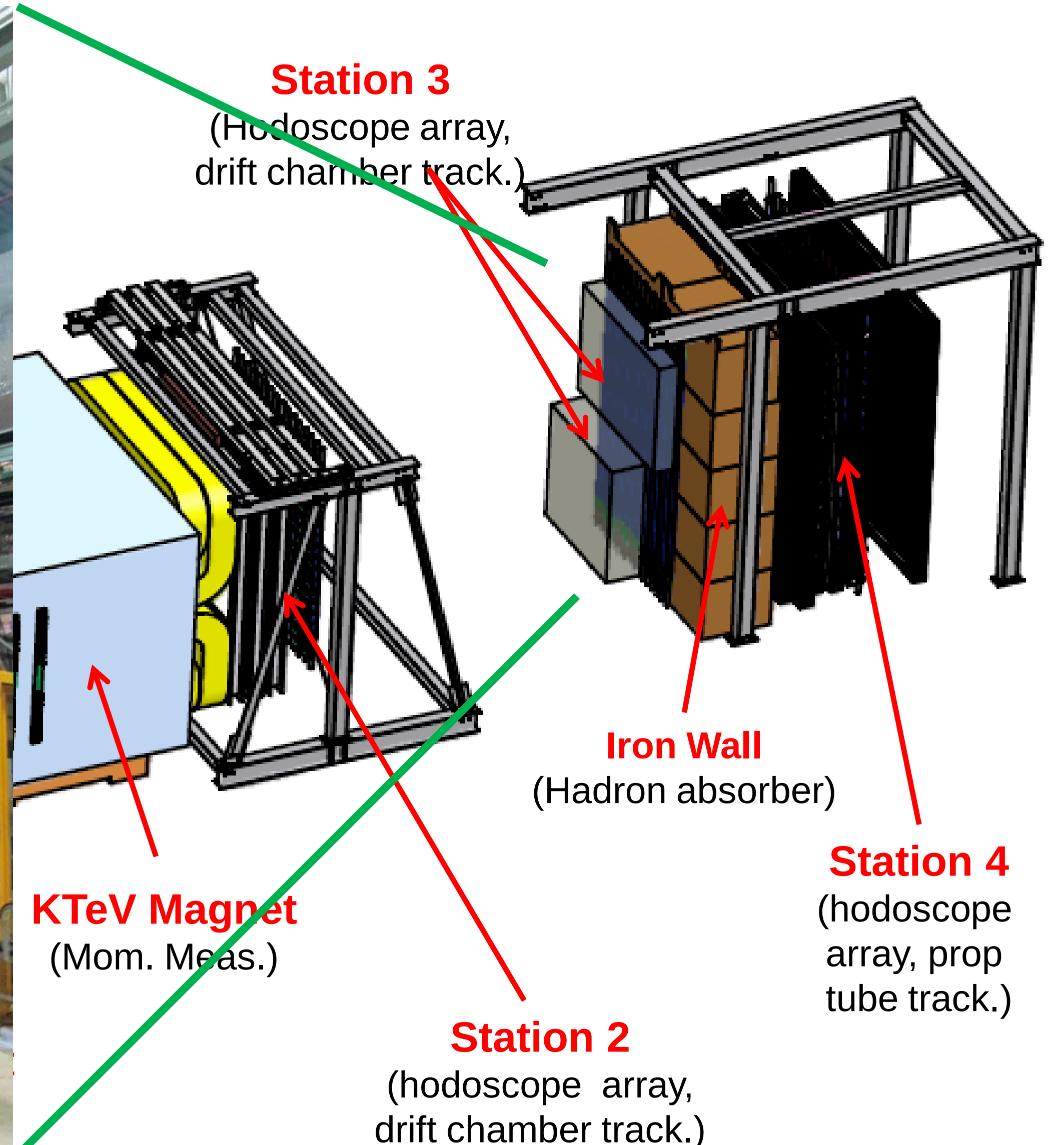
Closed-aperture



Beam-dump (Cu)



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

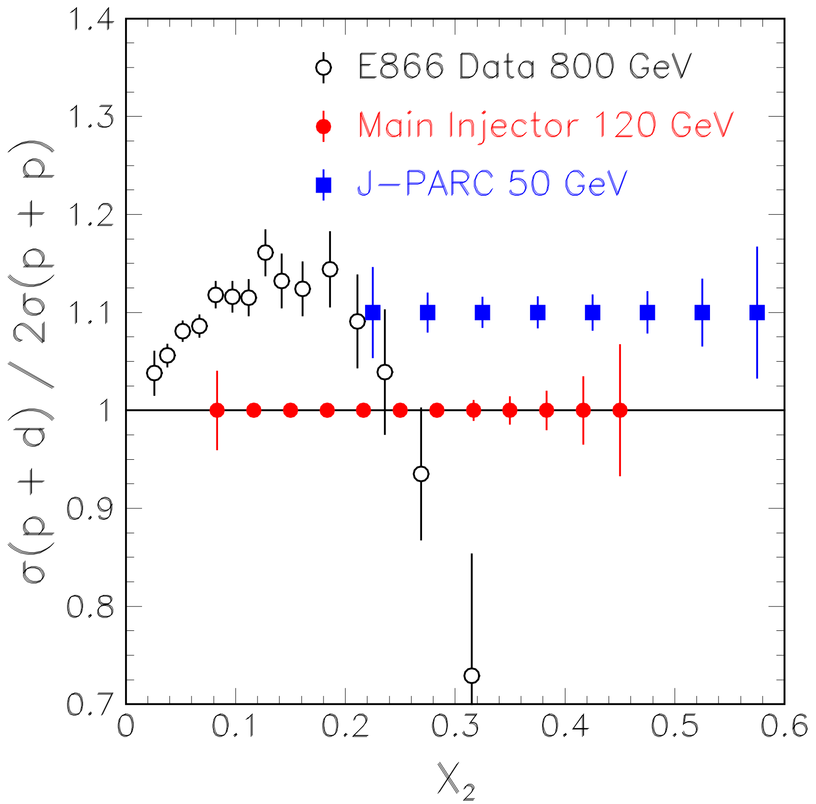


and solid targets)

beam dump)

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)

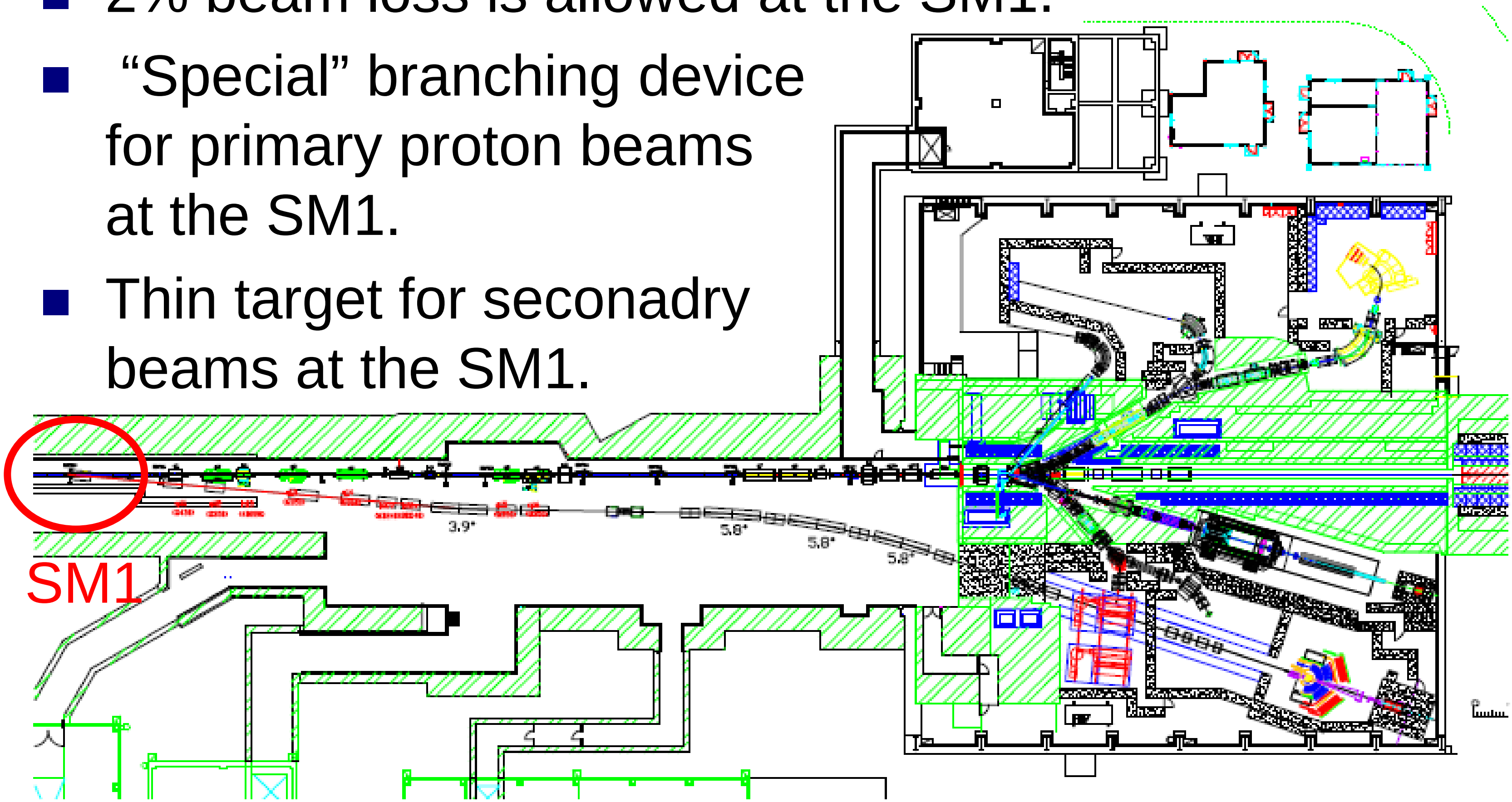
50-cm long LH_2 / LD_2 targets

60-day runs for each targets

assuming 50% efficiency

High-Momentum Beam Line

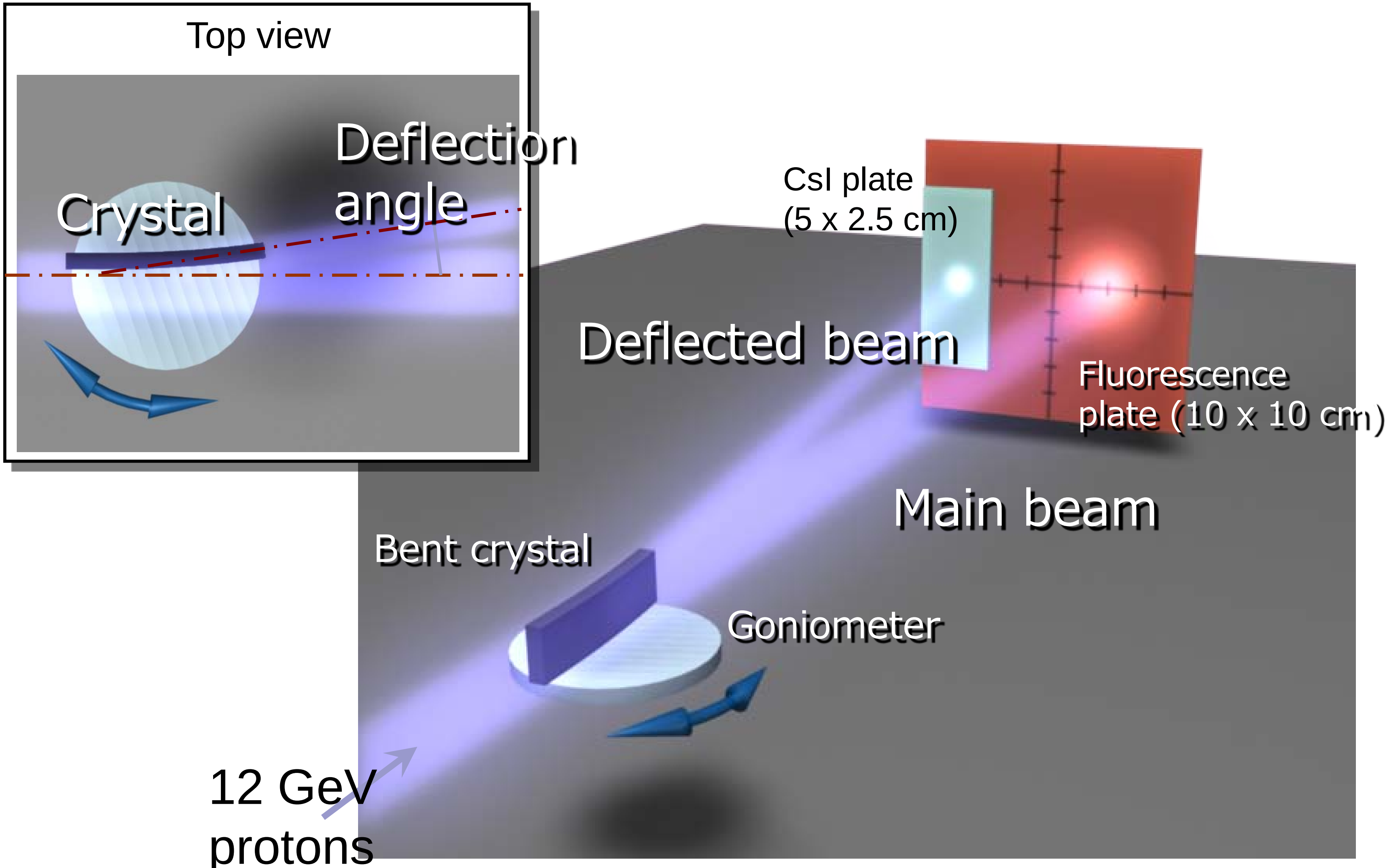
- Separated at the SM1 in the switchyard.
- 2% beam loss is allowed at the SM1.
- "Special" branching device for primary proton beams at the SM1.
- Thin target for seconadry beams at the SM1.



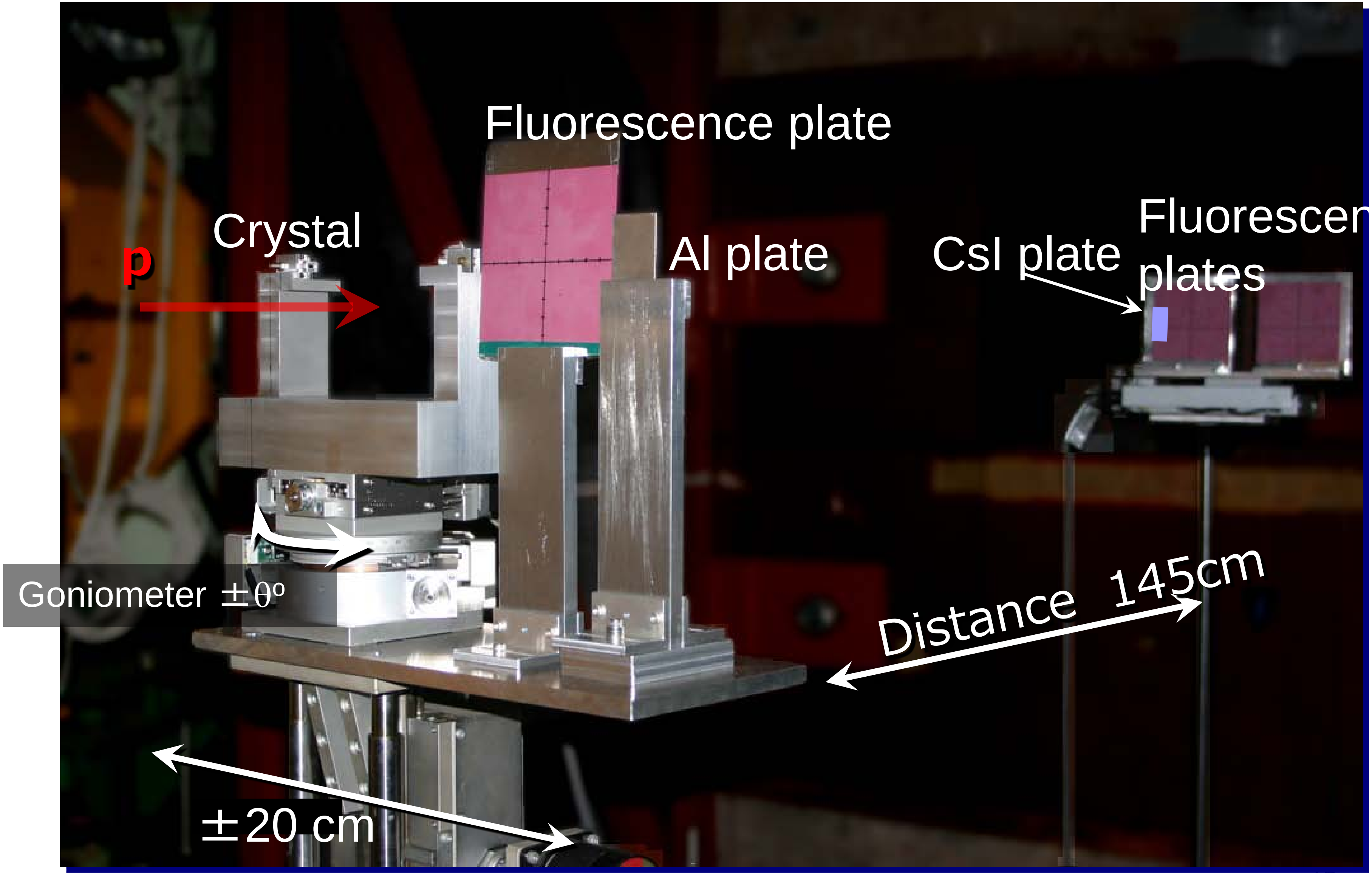
Device R&D for proton beam branching

- Main beam: 10^{13} – 10^{14} protons/spill
  → 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.

Schematic drawing of the experiment

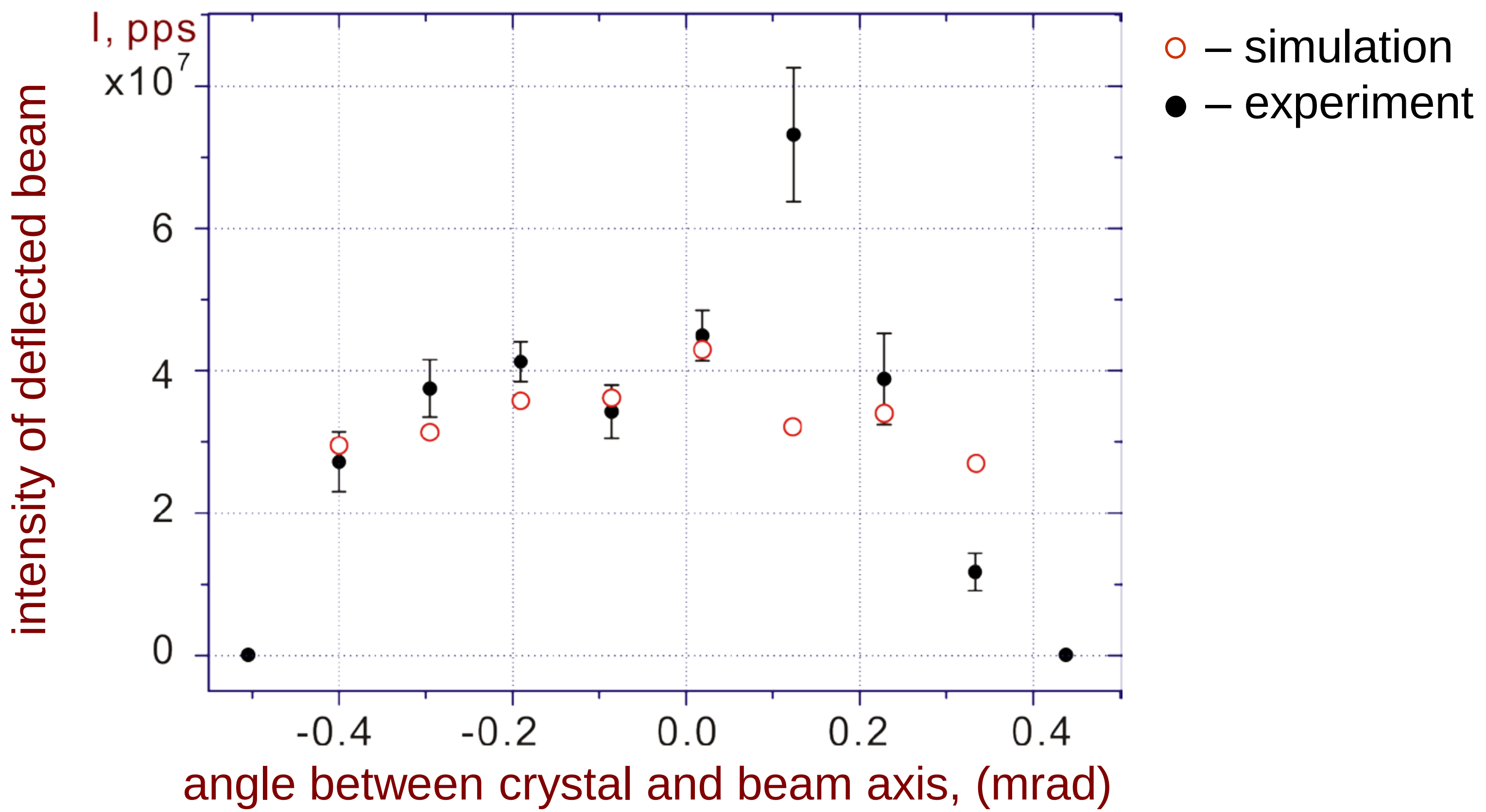


Experimental setup



Simulation vs. Experimental data

Experimental intensity of the deflected beam compared with the best fitted simulation (CATCH) for the beam divergence of **0.6 mrad** and normalization factor for the d. b. intensity of **1/0.93**.

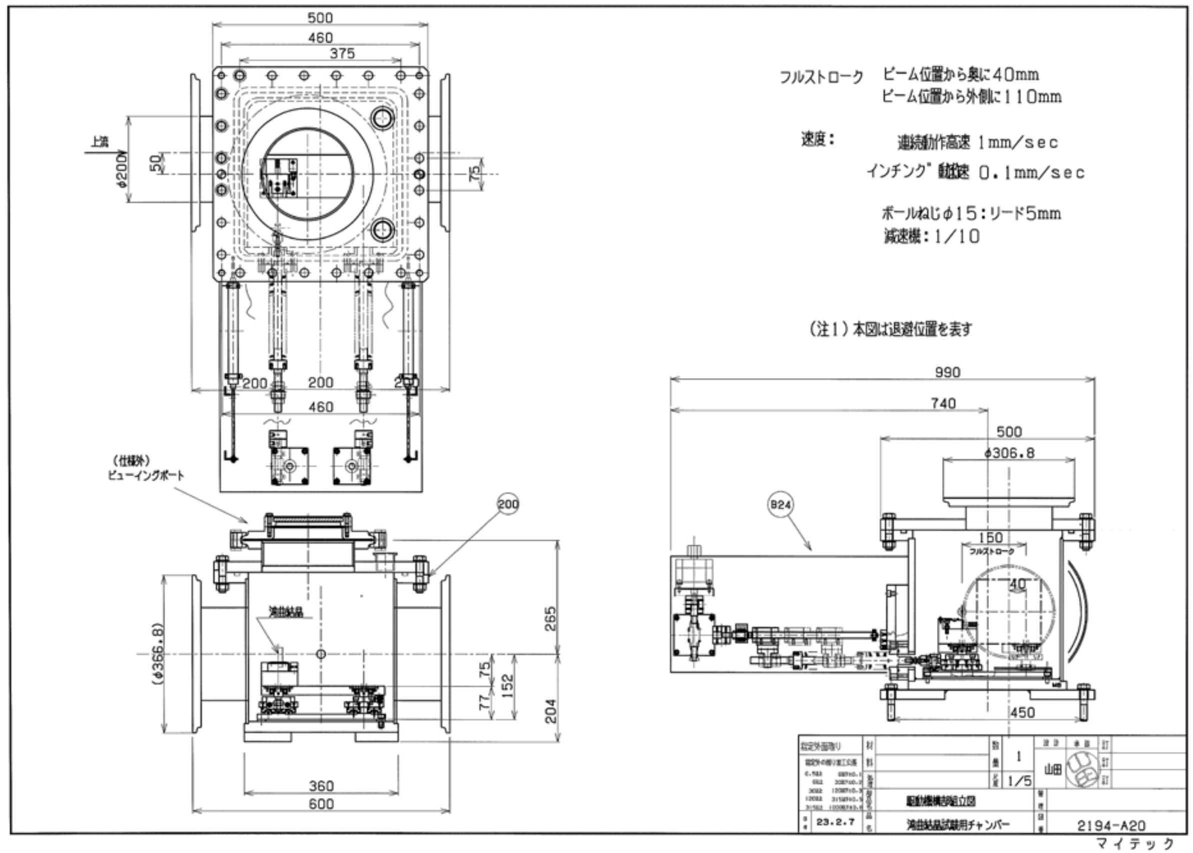


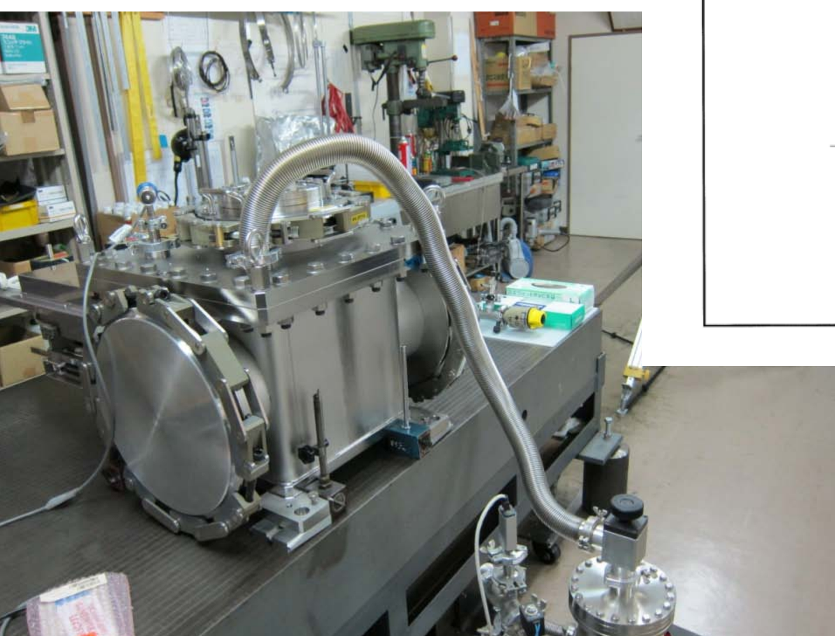
Branching of 10^7 protons from 10^{12} ppp was achieved.

R&D Issues at J-PARC

- Crystal fabrication
  - Crystals were made by Italian and Russian collaborators so far.
  - A test to fabricate a thick (~1mm) bent silicon crystal has been started at a company in Japan. → First crystal to be fabricated this year.
- Radiation and heat resistant goniometer system inside the vacuum at the separation point
  - Vacuum chamber and goniometer system have been fabricated.
- Radiation hardness is to be tested.

Goniometer / Vacuum Chamber





Beam test to be done at the next beam time!

Hadron Spectroscopy with Higher Momentum (Separated) Beams?

Ξ Hyperon Engineering

http://hyperon.net/

Ξ^-

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

$\Xi(1690)$

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

$\Xi(1950)$

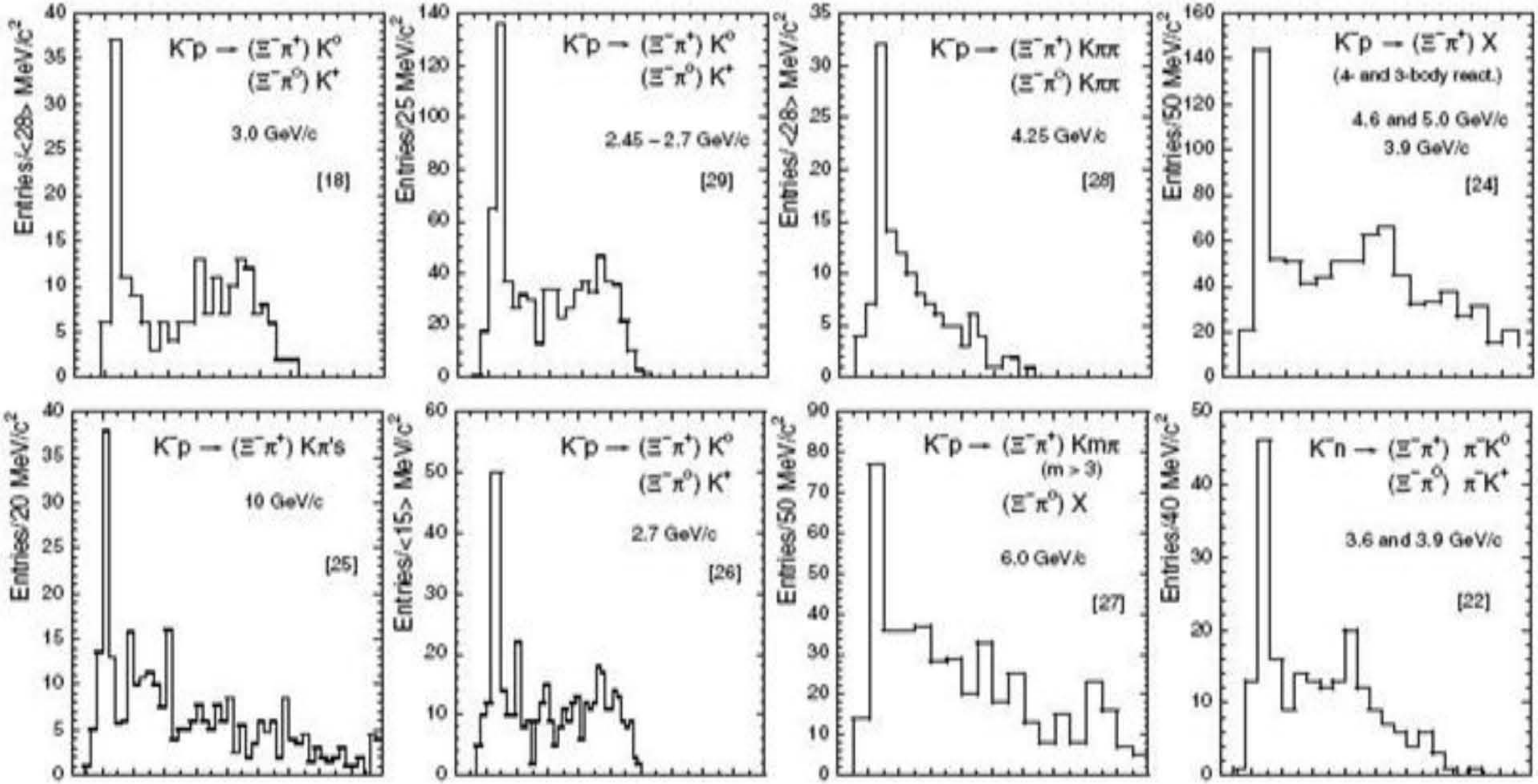
$\Xi(2030)$

TABLE I: The status of the Ξ resonances.

Particle	$L_{2I,2L}$	Status	$\Xi\pi$	ΛK	ΣK	$\Xi(1530)\pi$	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

Compilation of Data on $\Xi^-\pi^{+0}$-Spectroscopy

H. G. Fischer and S. Wenig, Eur. Phys. J. C **37**, 133 (2004).



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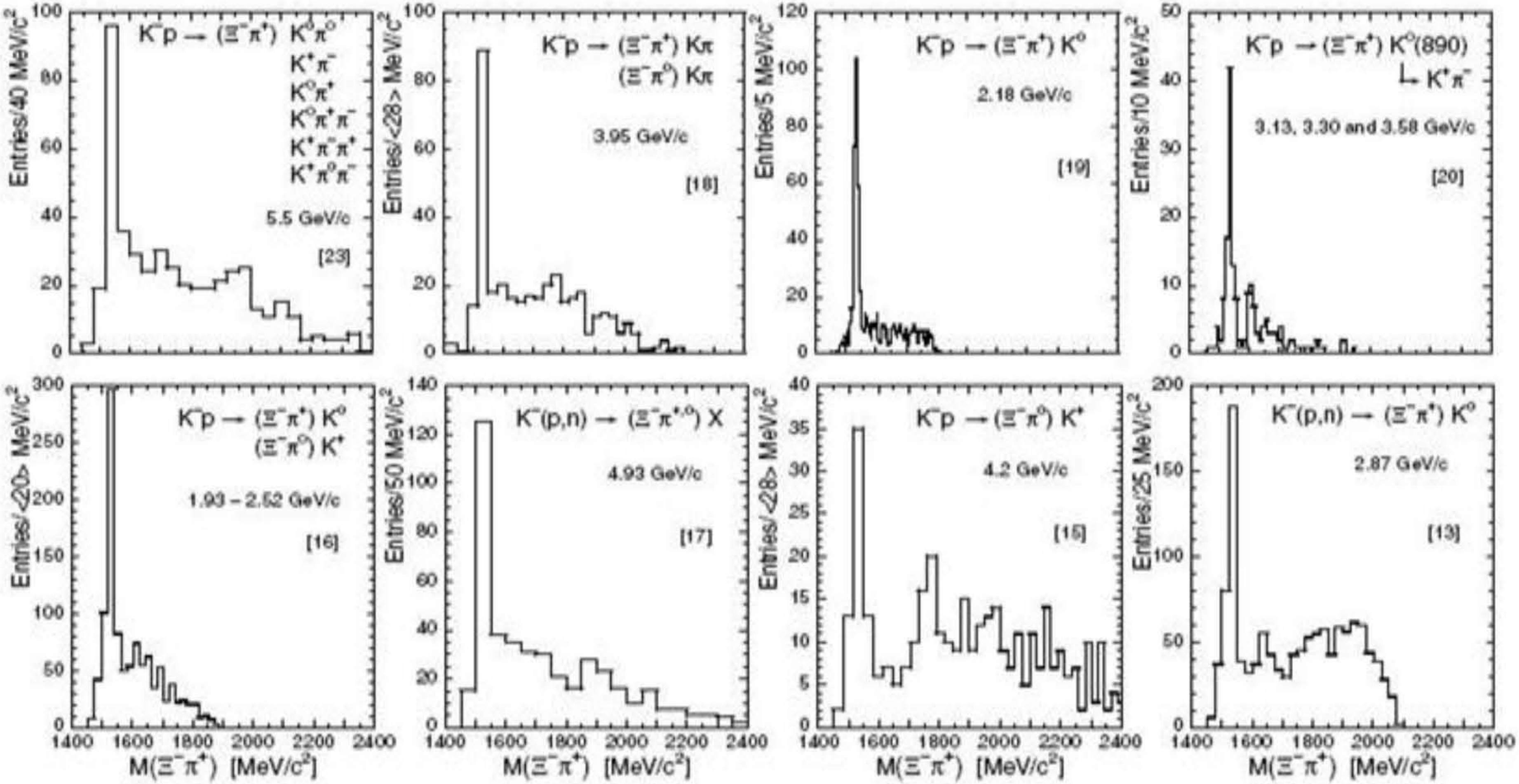
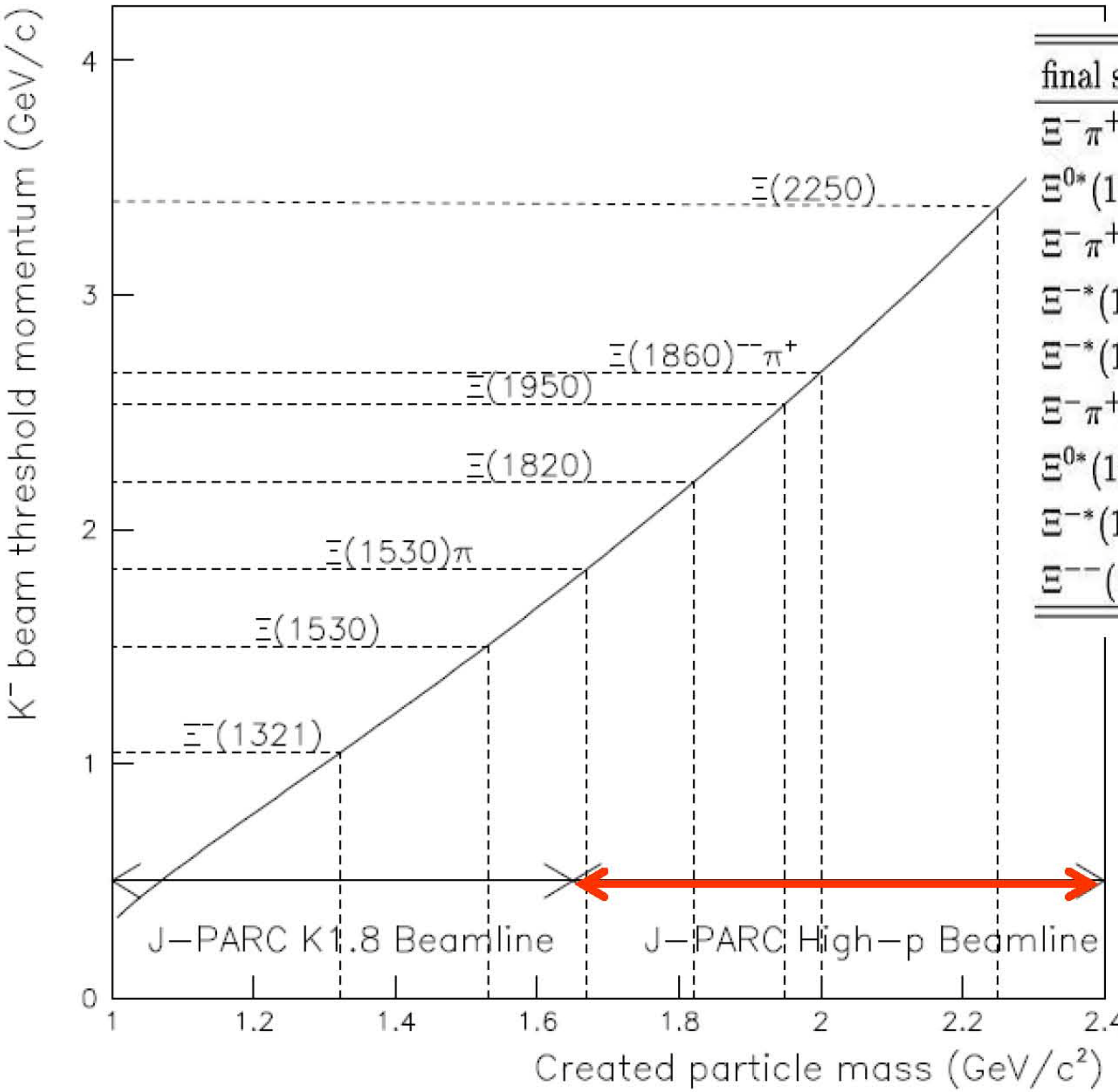




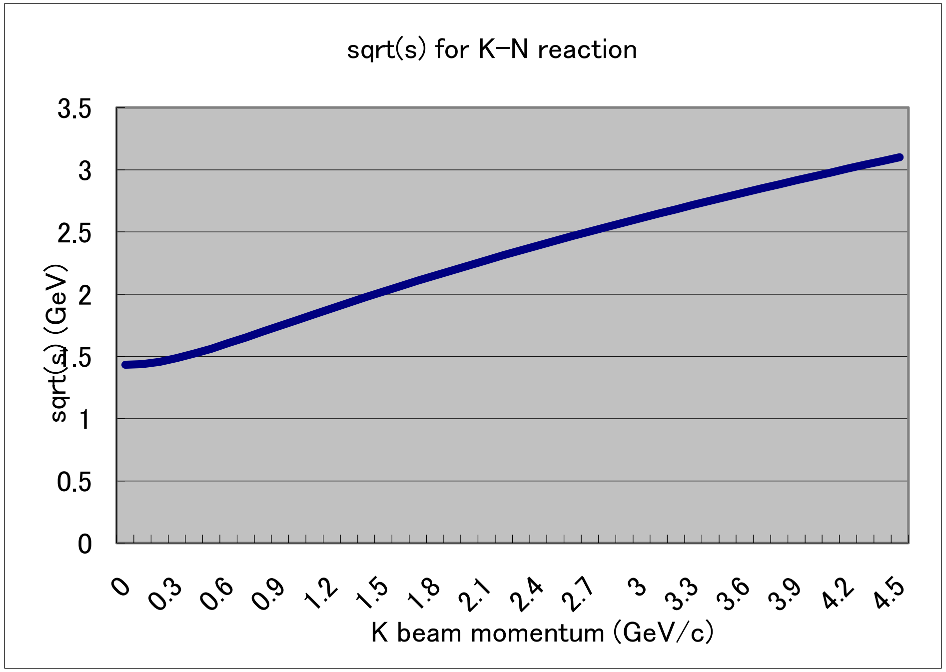
final state	p_{th}(GeV)	$\sigma(\mu\mathrm{b})$
$\Xi^-\pi^+\pi^-K^+$	1.666	13[a], 26[b], 3[e]
$\Xi^{0*}(1530)\pi^-K^+$	1.834	11.6[b], 9[e]
$\Xi^-\pi^+\pi^-\pi^0K^+$	1.989	25.4[d]
$\Xi^{-*}(1530)\pi^+\pi^-K^+$	2.184	
$\Xi^{-*}(1820)K^+$	2.206	4[a], 2.5[b]
$\Xi^-\pi^+K^{0*}(892)$	2.309	10.5[b], 4[d]
$\Xi^{0*}(1530)K^{0*}(892)$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

Hadron Structure / Spectroscopy?

- Just a hunt of missing resonances enough to be pursued??
- How can we achieve a breakthrough??
  - Omega production?

- Anyway, let's think about a separated high momentum beams!

π/K beam for excited baryons



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

Unseparated Beams (30GeV)

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

	Momentum (GeV/c)	$d\sigma/dpd\Omega$ (mb/sr/GeV/c)	Yield at SM1 (per 10^{14} protons)	Yield at 120m (per 10^{14} protons)
π^+	5	1400	3.7E7	2.4E7
π^+	10	210	1.1E7	8.9E6
π^-	5	1000	2.6E7	1.7E7
π^-	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!

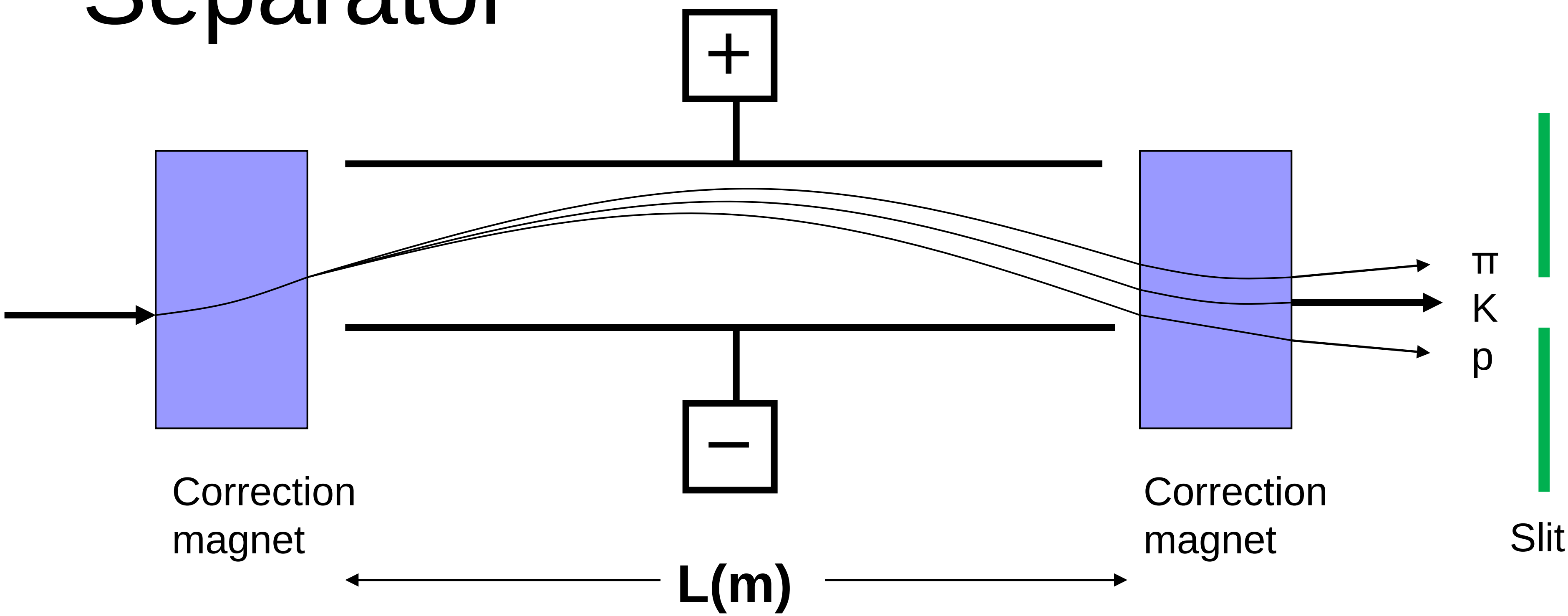
Unseparated Beams (50GeV)

- 50GeV protons + 2% loss copper target. Production angle of 4 degree and $(\Delta p/p)\Delta\Omega$ = 0.2msr%.

	Momentum (GeV/c)	$d\sigma/dpd\Omega$ (mb/sr/GeV/c)	Yield at SM1 (per 10^{14} protons)	Yield at 120m (per 10^{14} protons)
π^+	5	3700	9.5E7	6.2E7
π^+	10	930	4.7E7	3.8E7
π^-	5	3700	9.5E7	6.2E7
π^-	10	700	3.6E7	2.9E7
K^+	5	440	1.1E7	4.4E5
K^+	10	120	6.2E6	1.2E6
K^-	5	220	5.7E6	2.3E5
K^-	10	56	2.9E6	5.8E5
pbar	5	53	1.4E6	1.4E6
pbar	10	16	8.4E5	8.4E5

- To get more intensity for higher momentum beams, extraction at more forward angles can be considered.

Principle of Electrostatic Separator



Displacement at exit: $\xi = eEL^2 / 2pc\beta$

Angle change at exit: $\Delta\theta = 2\xi / L$

Electrostatic Separator

- Sample calculation with L=6m and E=600kV/10cm

Momentum GeV/c	Particle	ξ (m)	Δθ (rad)	Δ at 3m (m)	Δ(K) – Δ(π) at 3m
1	π	0.109	0.0362	0.218	23 mm
	K	0.120	0.0402	0.241	
	p	0.148	0.0494	0.296	
2	π	0.0541	0.0180	0.108	3 mm
	K	0.0556	0.0185	0.111	
	p	0.0596	0.0199	0.119	
3	π	0.0360	0.0120	0.0720	1.1 mm
	K	0.0365	0.0122	0.0731	
	p	0.0377	0.0126	0.0755	
4	π	0.0270	0.00901	0.0540	0.4 mm
	K	0.0272	0.00907	0.0544	
	p	0.0277	0.00924	0.0554	

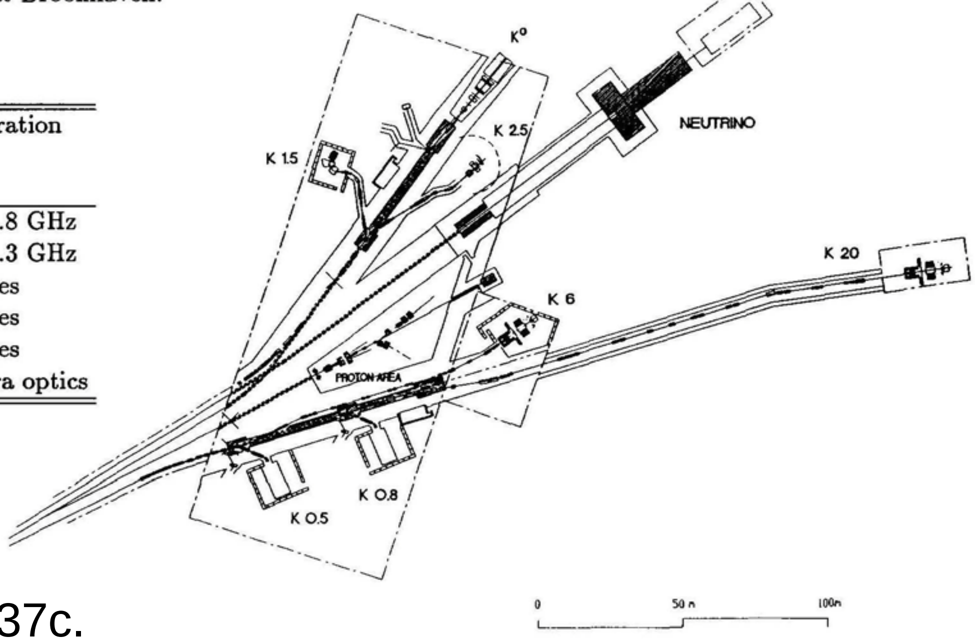
- Need huge ES separator (~30m for 6 GeV/c) or RF separator!

K6 Beam Line at KAON Factory (TRIUMF)

ıt Brookhaven.

Properties of Separated Beams at KAON.

Channel	Momentum GeV/c –	Solid Angle msr $\Delta p/p$ in %	Momentum Acceptance	Length m	Type of Separation
K20	20 – 6	0.1	1	160	rf, 3 cavities, 2.8 GHz
K6	6 – 2.5	0.08 – 0.30	3	110	rf, 3 cavities, 1.3 GHz
K2.5	2.5 – 1.25	0.5 –2.0	4	54	dc, 2 stages
K1.5	1.5 – 0.75	2.0	4	30	dc, 2 stages
K0.80	0.80 – 0.55	6.0	5	18	dc, 2 stages
K0.55	0.55 – 0.40	8.0	6	14	dc, 1 stage, extra optics

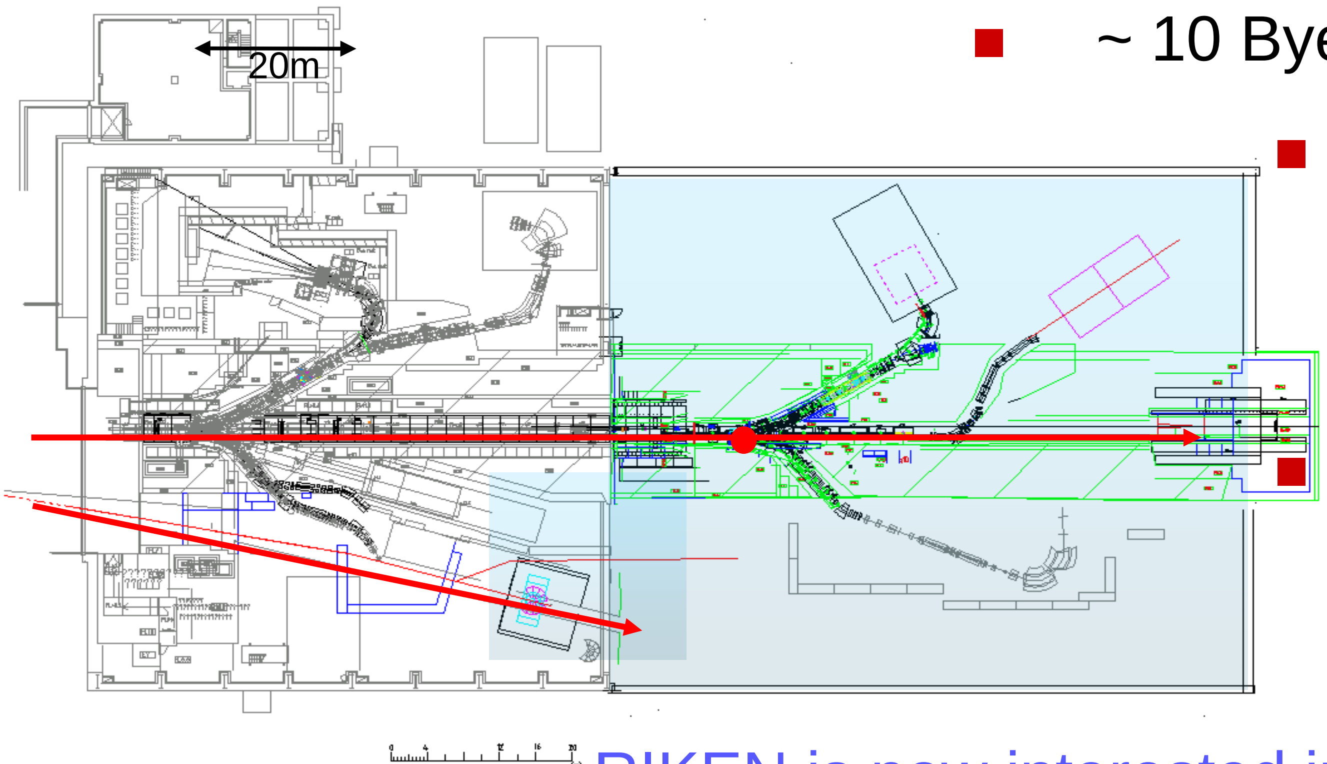


E. Vogt, Nucl. Phys. A558 (1993) 537c.

- RF separator needs ~100m length.
- Separated high-momentum beam needs Extension of Hadron Hall.

Extension of Hadron Hall

- Extend Hadron Hall
- Install the 2nd production target
- Install several beam lines
- Install spectrometers for hadron physics
- ~ 10 Byen (~ $80M)
- Concrete plan of the beam lines and detectors is to be discussed.
- Good physics cases needed to realize high-mom separated beams.



RIKEN is now interested in contributing to the extension.

Summary

- Hadron Experimental Facility of J-PARC started its physics run in the fall of 2010.
- The huge earthquake assaulted J-PARC also, but there were no injuries and building collapses at J-PARC.
- Detailed investigation including precise survey is being done. A goal is to resume the proton beam around the end of this year.
- In addition to so-called hypernuclear physics activity, J-PARC should be a good play ground for more hadron physics.
- Experiments at the high-p beam line should come soon.
- R&D for the high-p beam line is being done. Budget request has been started.
- Do we have enough-exciting physics for separated high-mom beams?
- Higher momentum separated beams (> 2 GeV/c) need a longer space. We welcome good physics cases for such a beam line at the extended Hadron Hall.