Hadron Physics at J-PARC

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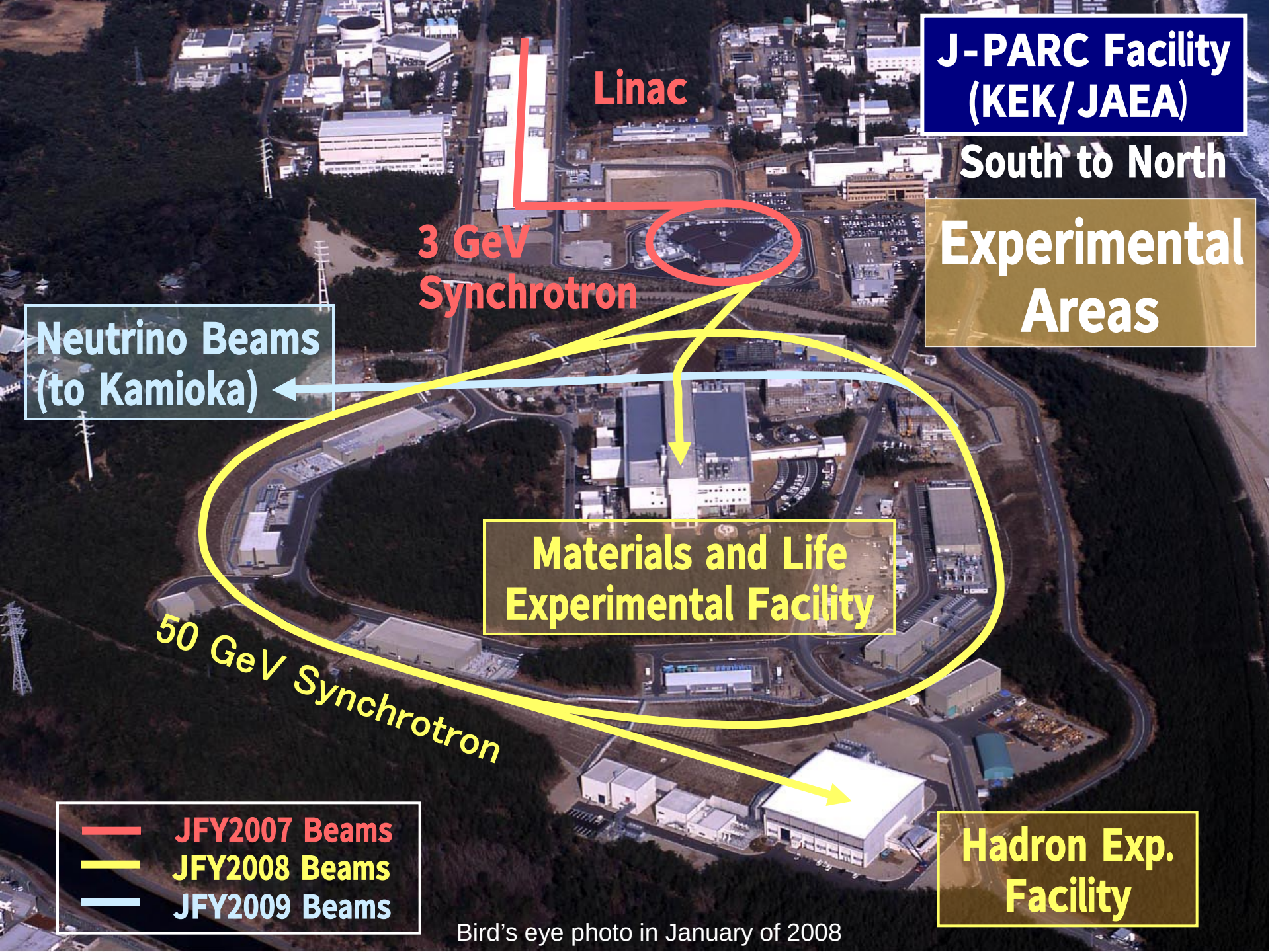
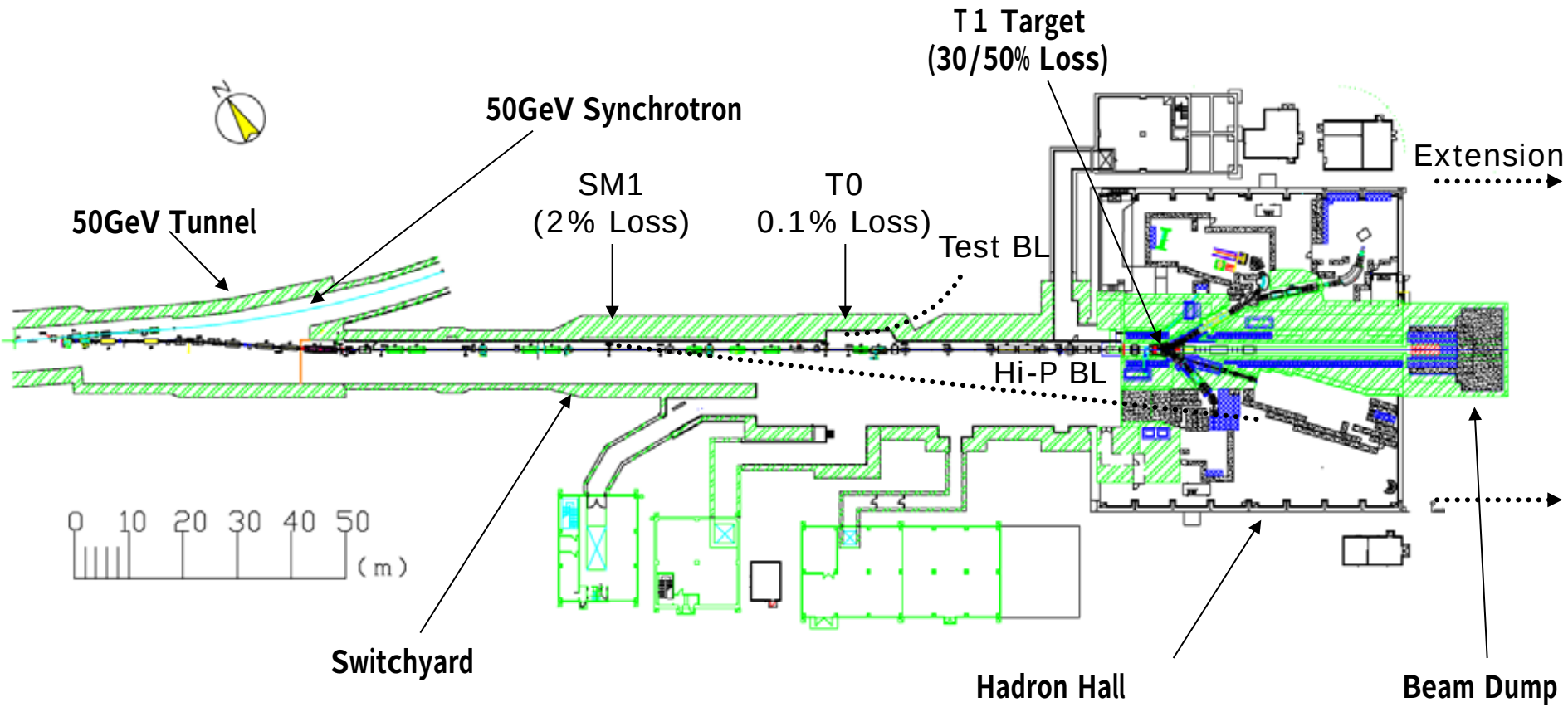
Contents

- J-PARC and Hadron Experimental Facility (Hadron Hall)
- Physics overview
- Fruits so far obtained
- High-momentum beam line
- Extension
- Summary



Bird's eye photo in January of 2008

Hadron Experimental Facility (Current Layout)



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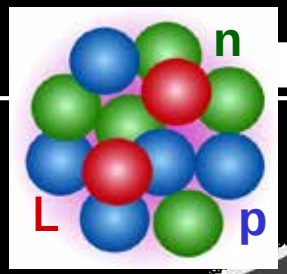
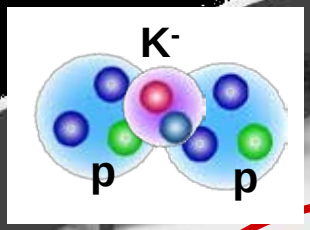
Slide By
H.Tamura

Hall



X hypernuclei
L L hypernuclei
X-atomic X-rays
L hypernuclear g rays
Neutron-rich L hypern.
Pentaquark Q^+ search
K^-pp bound state

Hyp. weak decay (A=4)
Hyp. weak decay (A=12)
p Double charge exch.
w mesonic nuclei
Sp scattering



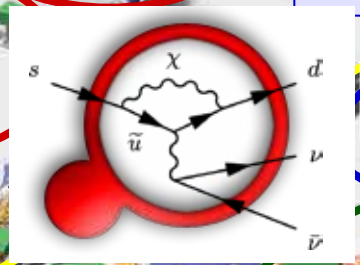
Dump

K1.8

K^0_L rare decays

Hadron mass in nuclei
Nucleon quark structure

K1.8BR



KL

K^-pp bound states
K^- atomic X rays
h mesonic nuclei

K1.1

High momentum line

Not constr

K1.1BR

T violation in K^+ decay
Universality in K^+ decay
Q^+ study by K^+n scattering

F mesonic nuclei
L hypernuclear g rays
S-nuclear systems
YN scatering
Q^+ hypernuclei

30~50 GeV
primary beam

Approved (stage-2) / (stage-1) / proposed,LOI

m-e conversion search

Physics with Low Momentum Secondary Beams

- So far there are only low-momentum beam lines.
- Strangeness nuclear physics
  - With (pi, K), (K, pi), and (K-, K+) reactions
- Other hadron physics
  - Many strangeness related, but a few non-strange.
- Low Momentum Secondary Beams
  - Pions and Kaons <2 GeV/c at K1.8 beam line
    - Momentum was selected so that the production cross section of the Xsi baryon is at the maximum.
    - Major goal is S=-2 hypernuclei (Xsi nuclei and double-Lambda nuclei).
    - Used also for (pi, K) reaction for single hypernuclei.
  - Pions and Kaons <1.1GeV/c at K1.8BR and K1.1 beam line
    - Single Lambda hypernuclei
      - Gamma ray spectroscopy
    - Search for K-pp bound states
- Neutral kaon beams: KOTO

Three Dimensional Nuclear Chart

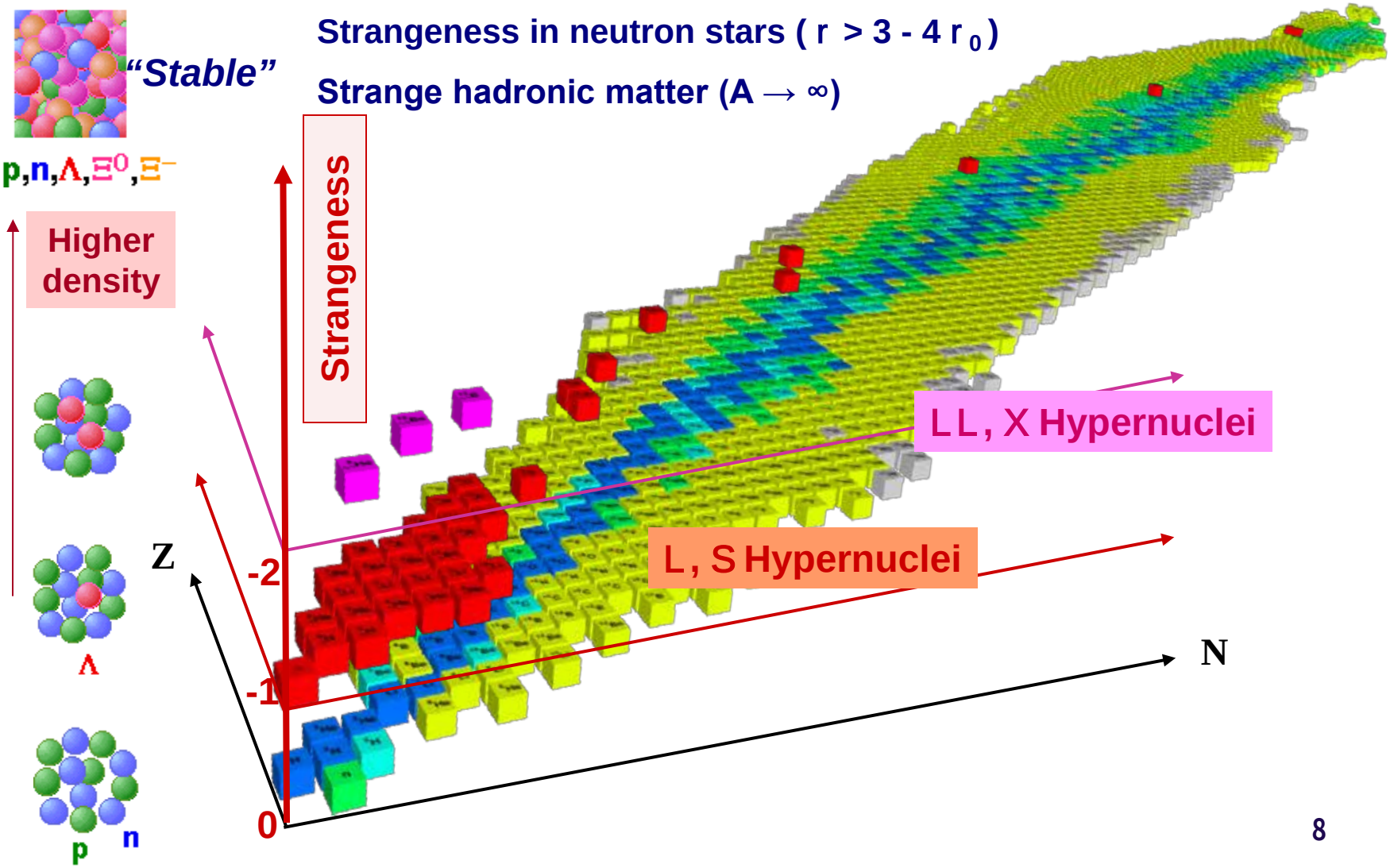
Nu ~ Nd ~ Ns

"Stable"

p,n,Λ,Ξ⁰,Ξ⁻

Strangeness in neutron stars (r > 3 - 4 r $_0$)

Strange hadronic matter (A → ∞)



Single strangeness experiments

- E19 (published): Pentaquark search
- E10 (published): Neutron-rich hypernuclei with double-charge exchange
- E13 (coming soon): Gamma ray spectroscopy of hypernuclei
- E15 (took some data): Search for K^-+p+p bound state
- … (many waiting)

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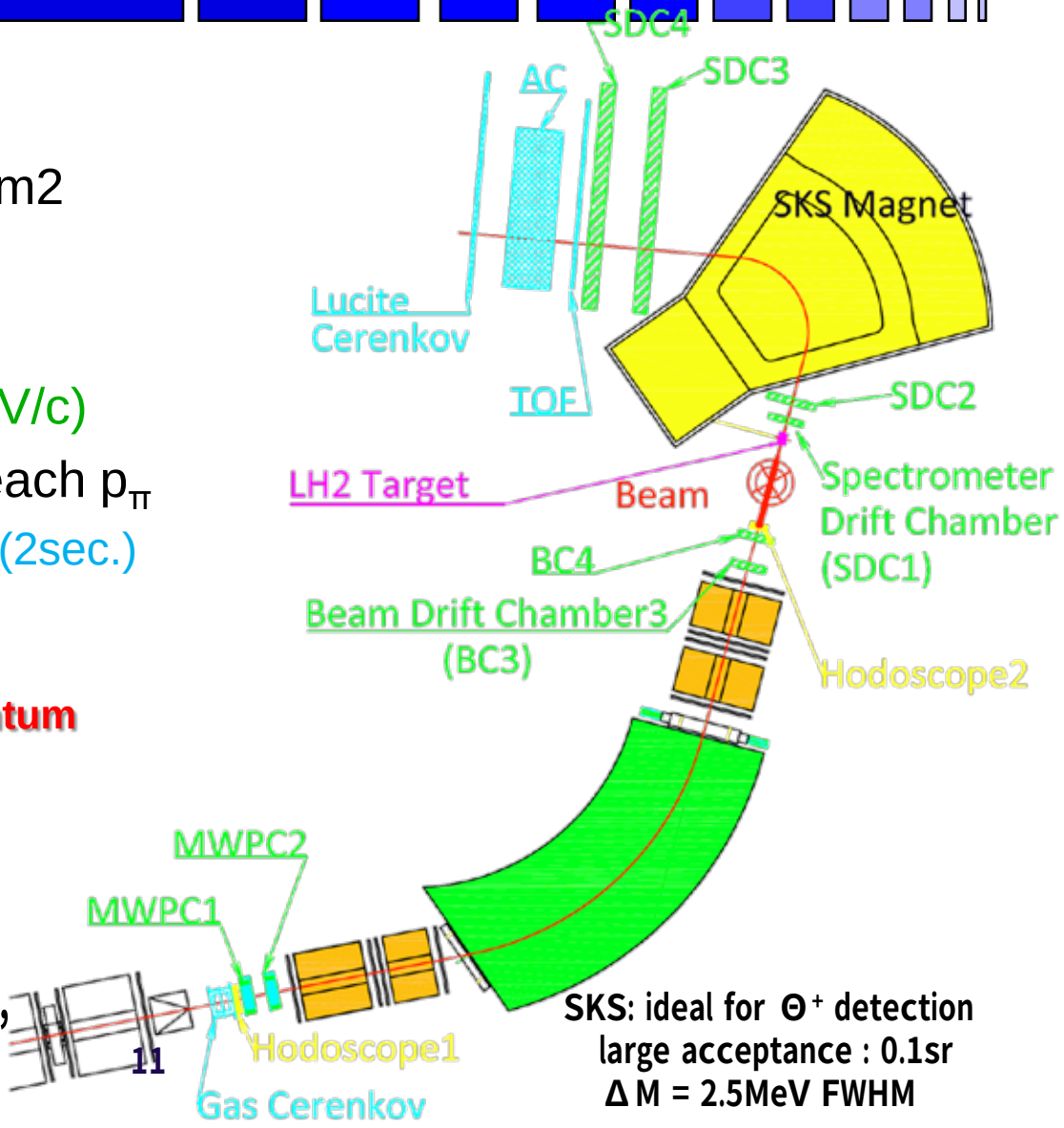
E19: Pentaquark Search

- search for Θ^+ in $p(\pi^-, K^-)$
- target : liquid H2, 0.86g/cm2
- at K1.8 beamline + SKS
- beam momentum :
  - p_π=(1.87,1.92,2.00GeV/c)
- 4.8 x 10^{11} p on target for each p_π
  - beam intensity : 10^7/spill(2sec.)
  - beam time : 160 hours

Yield : 10^4 events for each momentum
Sensitivity : 75nb/sr
à confirm the existence of Θ^+

E19 took the first physics data with p=1.92 GeV/c in Oct/Nov, 2010, and p=2.0 GeV/c in Feb, 2012.



E19: Pentaquark Search

PRL 109, 132002 (2012) PHYSICAL REVIEW LETTERS week ending 28 SEPTEMBER 2012

Search for the Θ^+ Pentaquark via the $\pi^- p \to K^- X$ Reaction at 1.92 GeV/c

K. Shirotori,[1,2,*,†] T. N. Takahashi,[3] S. Adachi,[4] M. Agnello,[5,6] S. Ajimura,[7] K. Aoki,[8] H. C. Bhang,[9] B. Bassalleck,[10] E. Botta,[11,6] S. Bufalino,[6] N. Chiga,[1] P. Evtoukhovitch,[12] A. Feliciello,[6] H. Fujioka,[4] F. Hiruma,[1] R. Honda,[1] K. Hosomi,[1] Y. Ichikawa,[4] M. Ieiri,[8] Y. Igarashi,[8] K. Imai,[2] N. Ishibashi,[13] S. Ishimoto,[8] K. Itahashi,[14] R. Iwasaki,[8] C. W. Joo,[9] M. J. Kim,[9] S. J. Kim,[9] R. Kiuchi,[9] T. Koike,[1] Y. Komatsu,[3] V. V. Kulikov,[15] S. Marcello,[11,6] S. Masumoto,[3] K. Matsuoka,[13] K. Miwa,[1] M. Moritsu,[4] T. Nagae,[4] M. Naruki,[8] M. Niiyama,[4] H. Noumi,[16] K. Ozawa,[8] N. Saito,[8] A. Sakaguchi,[13] H. Sako,[2] V. Samoilov,[12] M. Sato,[1] S. Sato,[2] Y. Sato,[8] S. Sawada,[8] M. Sekimoto,[8] H. Sugimura,[4] S. Suzuki,[8] H. Takahashi,[8] T. Takahashi,[8] H. Tamura,[1] T. Tanaka,[13] K. Tanida,[9,2] A. O. Tokiyasu,[4] N. Tomida,[4] Z. Tsamalaidze,[12] M. Ukai,[1] K. Yagi,[1] T. O. Yamamoto,[1] S. B. Yang,[9] Y. Yonemoto,[1] C. J. Yoon,[9] and K. Yoshida[13]

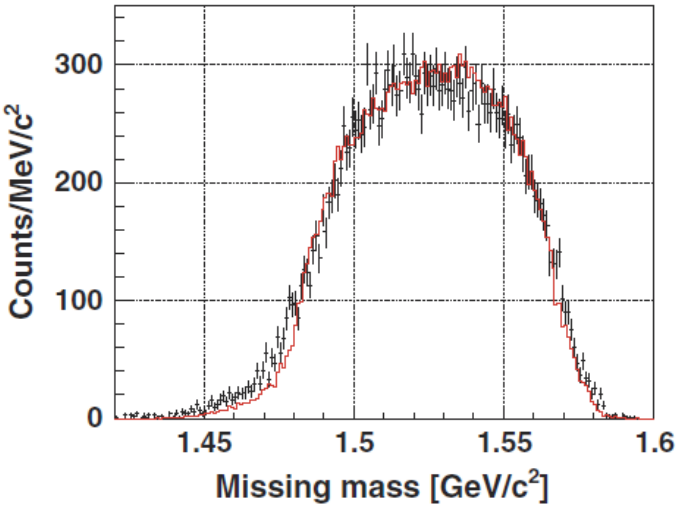


FIG. 2 (color). The missing mass spectrum and the background shape for the $\pi^- p \to K^- X$ reaction at 1.92 GeV/c. The black points with error bars are the experimental data. The contribution of the simulated background is indicated by the red histogram.

No significant peak was observed.

E10：Spectroscopy of neutron-rich Λ hypernucleus $^{5}_{\Lambda}$H by double charge exchange (p-,K+) reaction

- How far can we extend the hypernucler chart?
  - Importance of the “glue-like role” of the Λ hyperon.
  - ΛN interaction may stabilize the host nucleus.

Physics Letters B 729 (2014) 39–44

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Search for $^{6}_{\Lambda}$H hypernucleus by the ^{6}Li(π^-, K^+) reaction at $p_{\pi^-} = 1.2$ GeV/c ☆

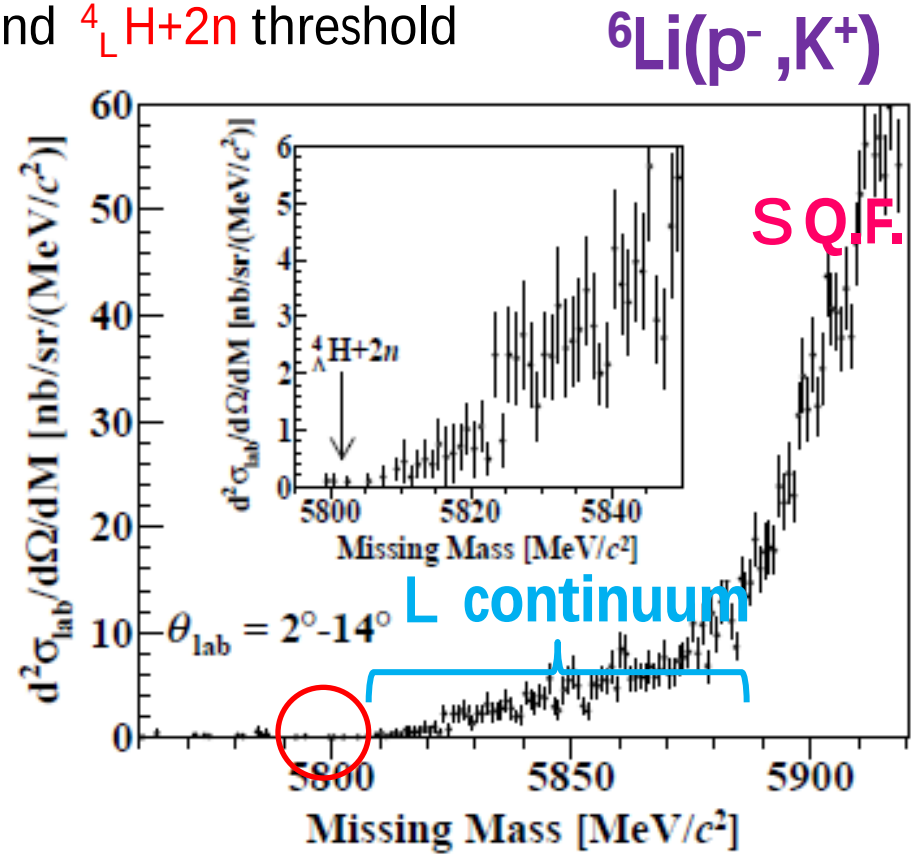
J-PARC E10 Collaboration

H. Sugimura [a,b,*], M. Agnello [c,d], J.K. Ahn [e], S. Ajimura [f], Y. Akazawa [g], N. Amano [a], K. Aoki [h], H.C. Bhang [i], N. Chiga [g], M. Endo [j], P. Evtoukhovitch [k], A. Feliciello [d], H. Fujioka [a], T. Fukuda [l], S. Hasegawa [b], S. Hayakawa [j], R. Honda [g], K. Hosomi [g], S.H. Hwang [b], Y. Ichikawa [a,b], Y. Igarashi [h], K. Imai [b], N. Ishibashi [j], R. Iwasaki [h], C.W. Joo [i], R. Kiuchi [i,b], J.K. Lee [e], J.Y. Lee [i], K. Matsuda [j], Y. Matsumoto [g], K. Matsuoka [j], K. Miwa [g], Y. Mizoi [l], M. Moritsu [f], T. Nagae [a], S. Nagamiya [b], M. Nakagawa [j], M. Naruki [a], H. Noumi [f], R. Ota [j], B.J. Roy [m], P.K. Saha [b], A. Sakaguchi [j], H. Sako [b], C. Samanta [n], V. Samoilov [k], Y. Sasaki [g], S. Sato [b], M. Sekimoto [h], Y. Shimizu [l], T. Shiozaki [g], K. Shirotori [f], T. Soyama [j], T. Takahashi [h], T.N. Takahashi [o], H. Tamura [g], K. Tanabe [g], T. Tanaka [j], K. Tanida [i], A.O. Tokiyasu [f], Z. Tsamalaidze [k], M. Ukai [g], T.O. Yamamoto [g], Y. Yamamoto [g], S.B. Yang [i], K. Yoshida [j]

E10：Spectroscopy of neutron-rich Λ hypernucleus $^{5}_{\Lambda}$H by double charge exchange (p^-,K^+) reaction

- Production by the ^{6}Li(p^-,K^+) reaction
  - data-taking during Dec.2012 – Jan. 2013.1
  - K1.8 beam line + SKS (p_p=1.2GeV/c, DM=3.2MeV/c^2(FWHM))
  - 12–14M p^-/spill (2.0sec) beam (D.F.~40%)
  - 1.65×10^{12} p^- on Target c.f. 3×10^{12} (proposal)
  - e ~ 50% due to multi-track (pile-up) event (bad D.F.)
- No peak structure was observed around $^{4}_{\Lambda}$H+2n threshold
  - U.L. 1.2nb/sr (90%CL)
- Phys. Lett. B 729 (2014) 39

→ **Talk by Sakaguchi-san.**



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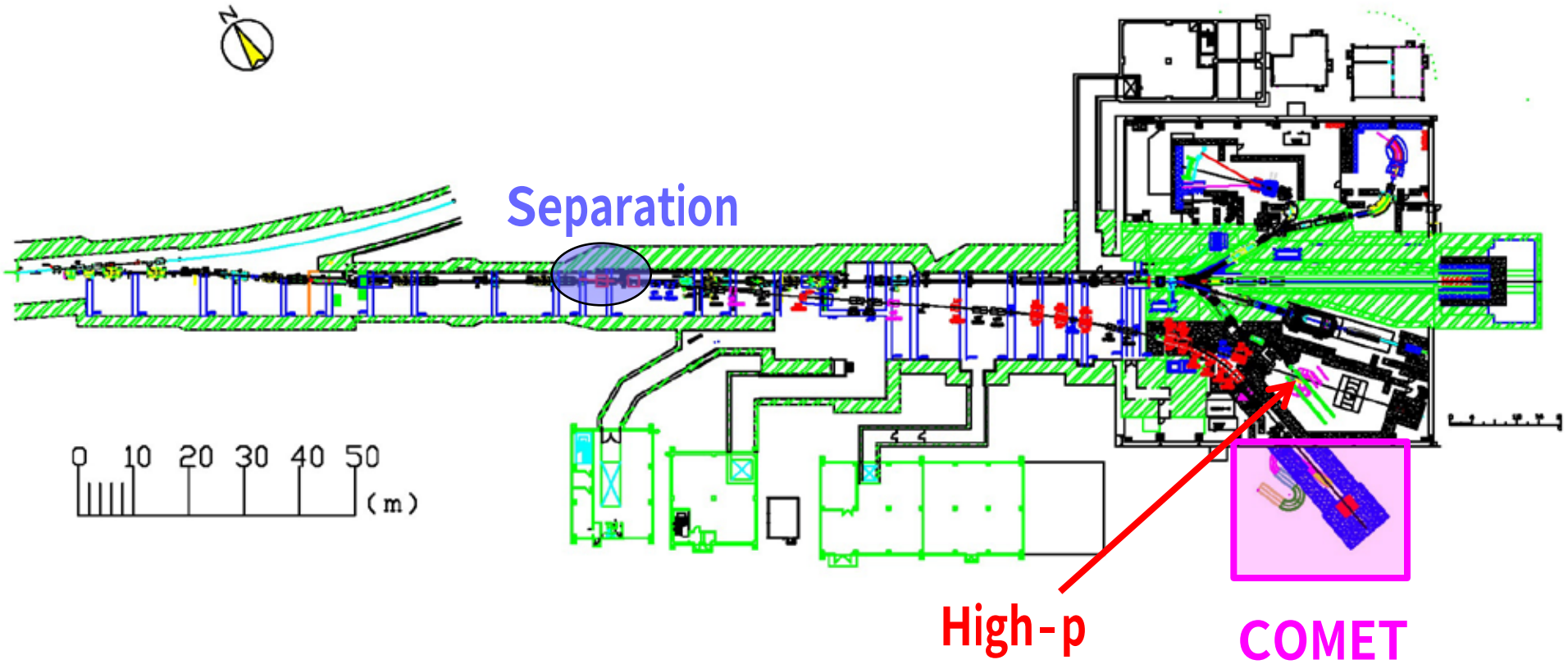
Physics with High-Momentum Beams

- "High-momentum beam line" (+ COMET beam line) has been funded!
- High-momentum primary proton beam (30GeV)
  - Meson mass modification inside nuclei
  - Dilepton measurement for nucleon and baryon structure
- High-momentum meson (pion) beam (~<15 GeV/c)
  - Pion-induced Drell-Yan?
  - Baryon spectroscopy with pion beams.

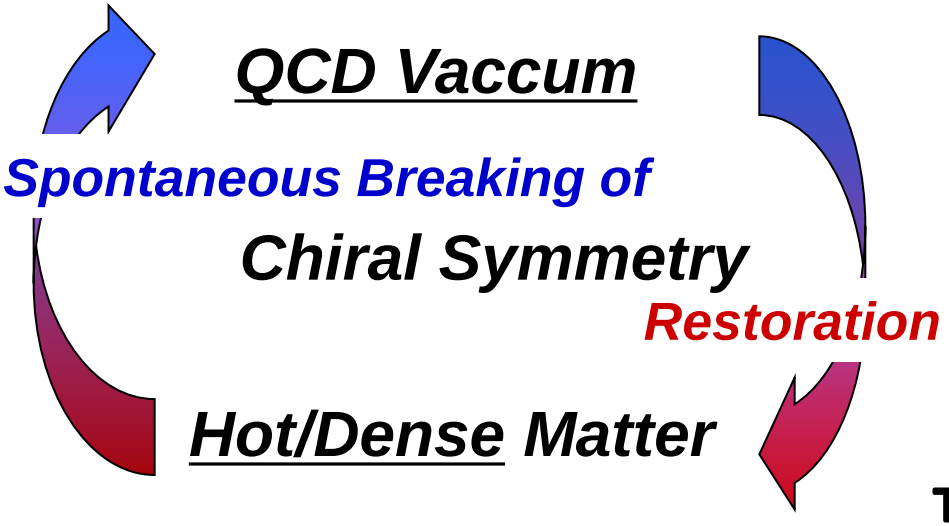
High-p and COMET

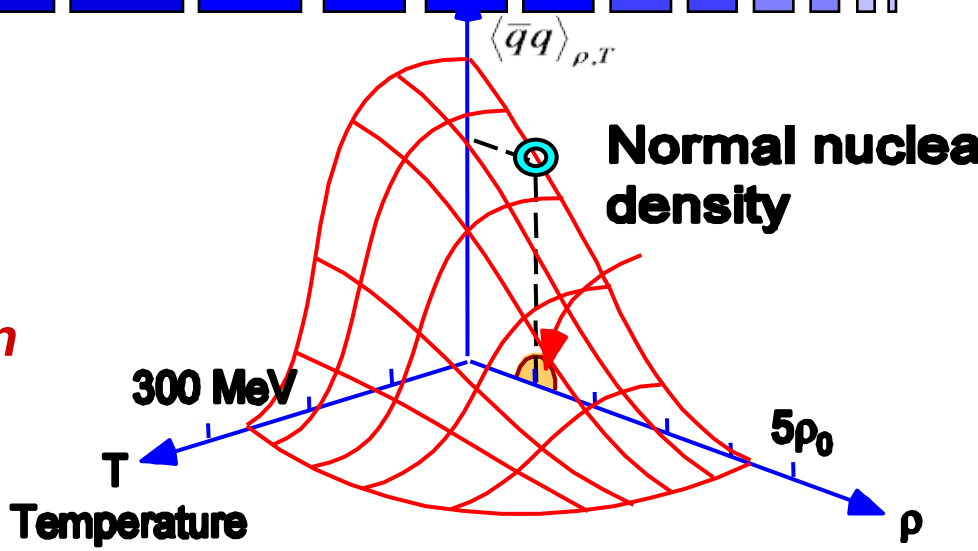
- New primary Proton Beam Line
  = High-momentum BL + COMET BL
- High-momentum Beam Line
  - Primary protons (~10^{10} – 10^{12}pps)
    - E16 (phi meson) is considered to be the first experiment.
  - Unseparated secondary particles (pi, …)
    - High-resolution secondary beam by adding several quadrupole and sextupole magnets.
- COMET
  - Search for mto e conversion
  - 8 GeV, 50 kW protons
  - Branch from the high-momentum BL
  - Annex building will be built at the south side.

New Primary Proton Beam Line



Mass modification of vector meson





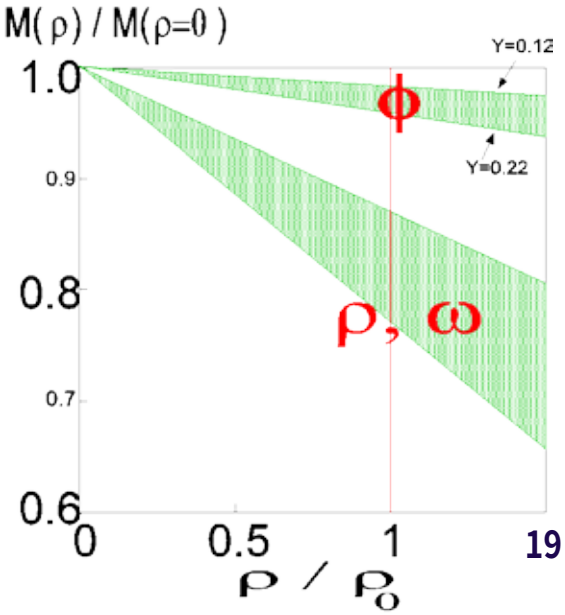
Vector meson mass
at normal nuclear density

$m^*/m=1-kr/r_0$

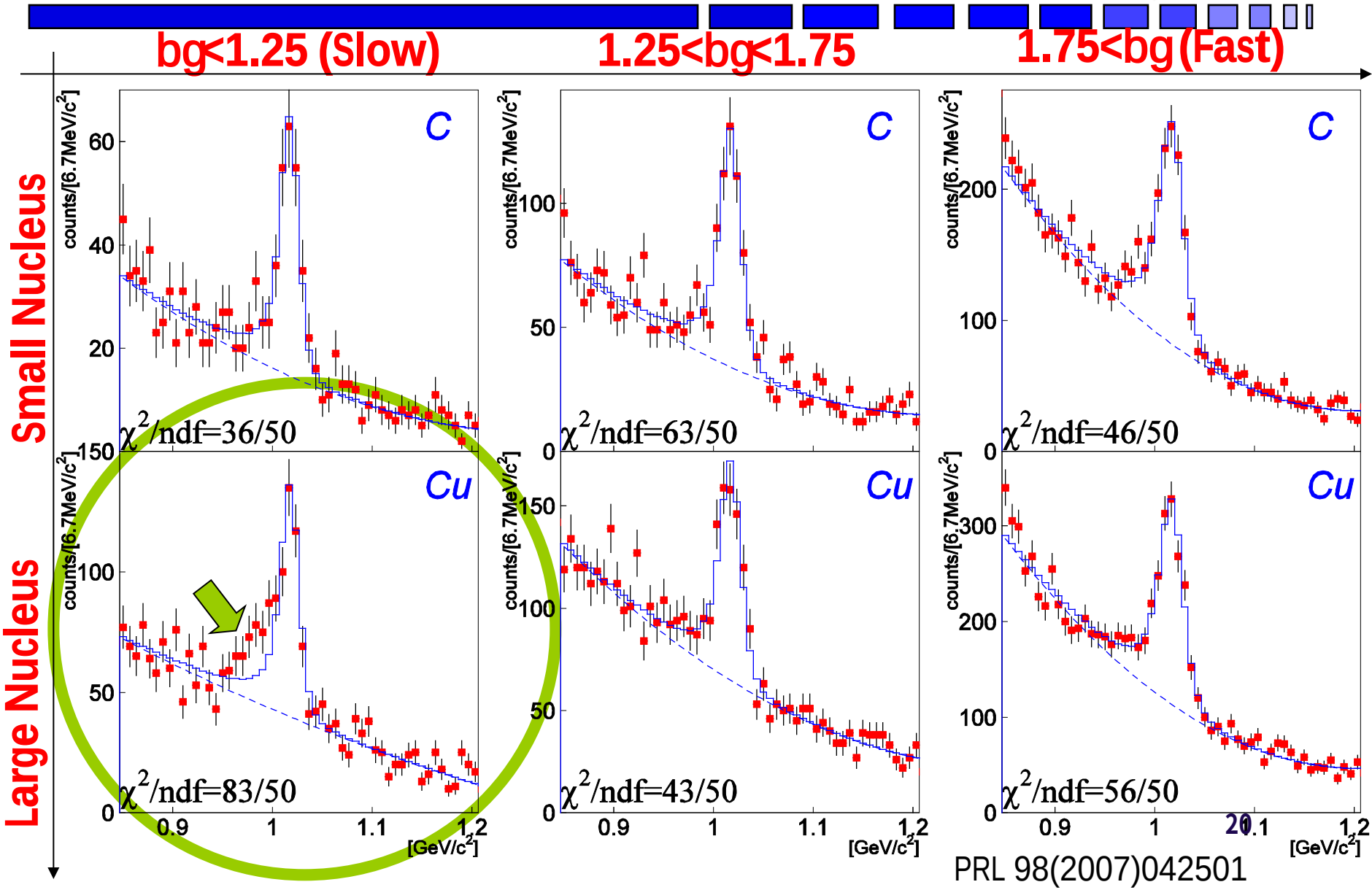
(Hatsuda&Lee PRC46(92)R34)

r /w : Dm = 130 MeV at r_0

f : Dm = 20~40 MeV at r_0

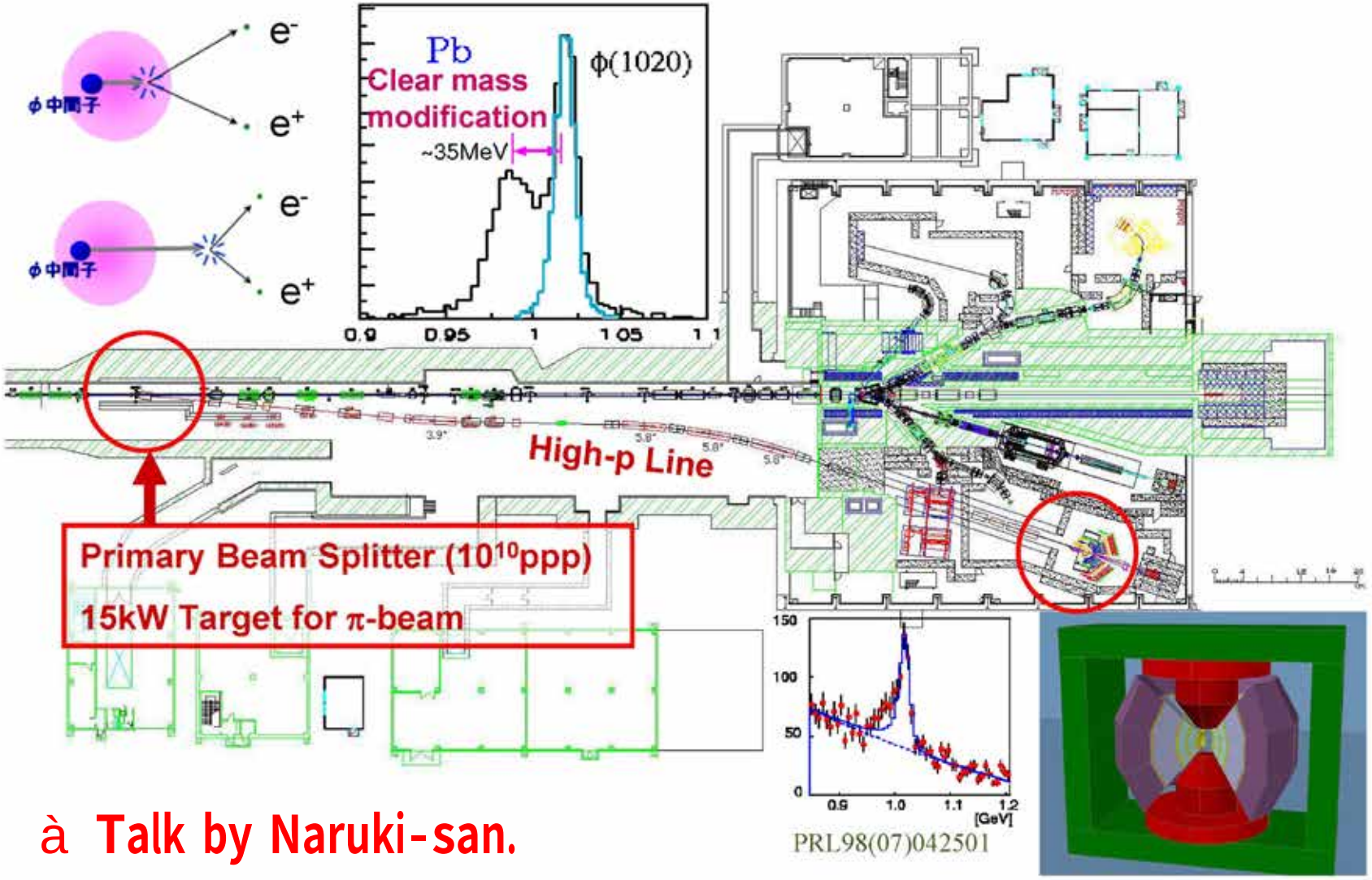


Results of a previous experiment (KEK-PS E325): Invariant mass spectra of f à e+e-



PRL 98(2007)042501

High-p Line and E16 Spectrometer

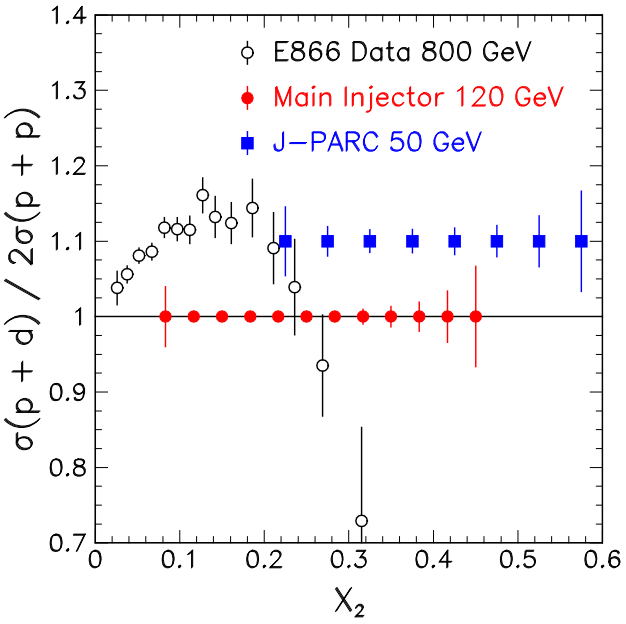


PRL98(07)042501

à **Talk by Naruki-san.**

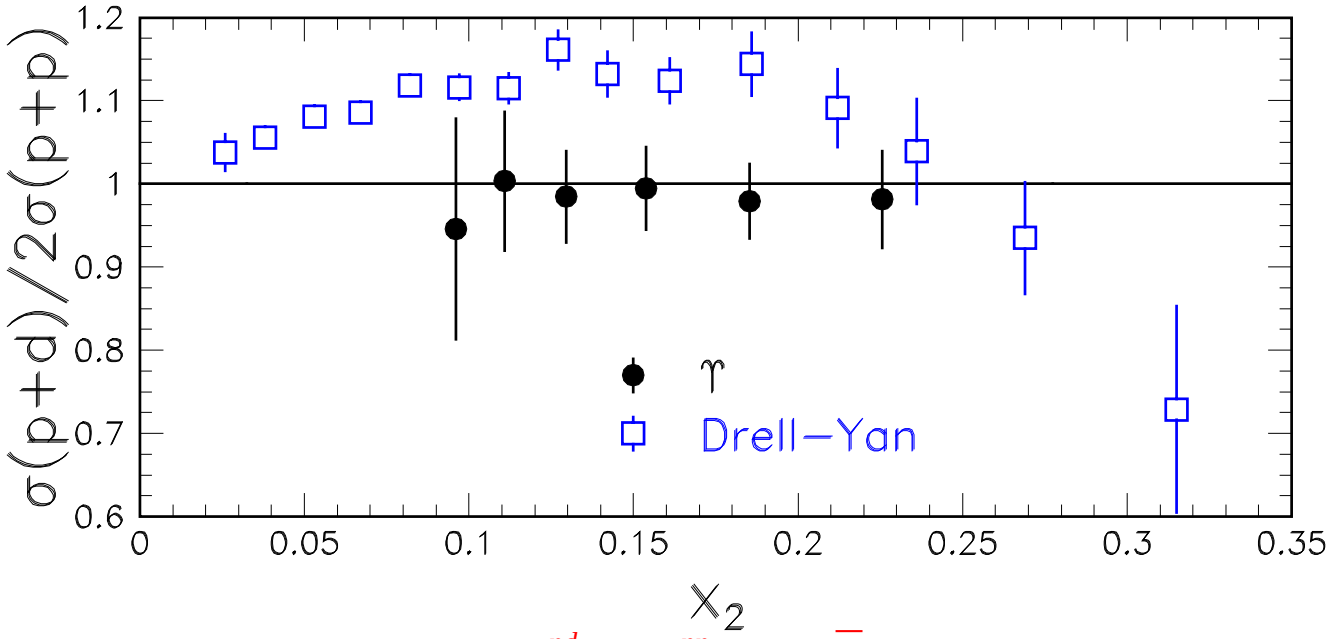
Possible hadron exps at high-momentum BL

- Sea quark structure through Drell-Yan measurement
  - Currently the E906/SeaQuest is running at Fermilab with 120-GeV protons to see d-bar/u-bar asymmetry.
  - Larger x possible with 50-GeV protons at J-PARC.
    - J-PARC is currently operated with 30-GeV and there are no demands of 50-GeV operation from other experiments, which needs modification of a part of the accelerator components.
  - There could be other possibilities of physics with dimuon measurement such as,
    - J/Psi measurements to see the nucleon sea,
    - dimuons from pion/kaon induced reactions to see meson-like substructure of a nucleon.
- Spin related quantities
  - Polarized beam relatively far future.
  - Polarized target would be available in the near future.
  - Measurement such as Bohr-Mulders can be carried out even with unpol. Drell-Yan measurements.



J/Psi: gg or q-qbar?

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



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

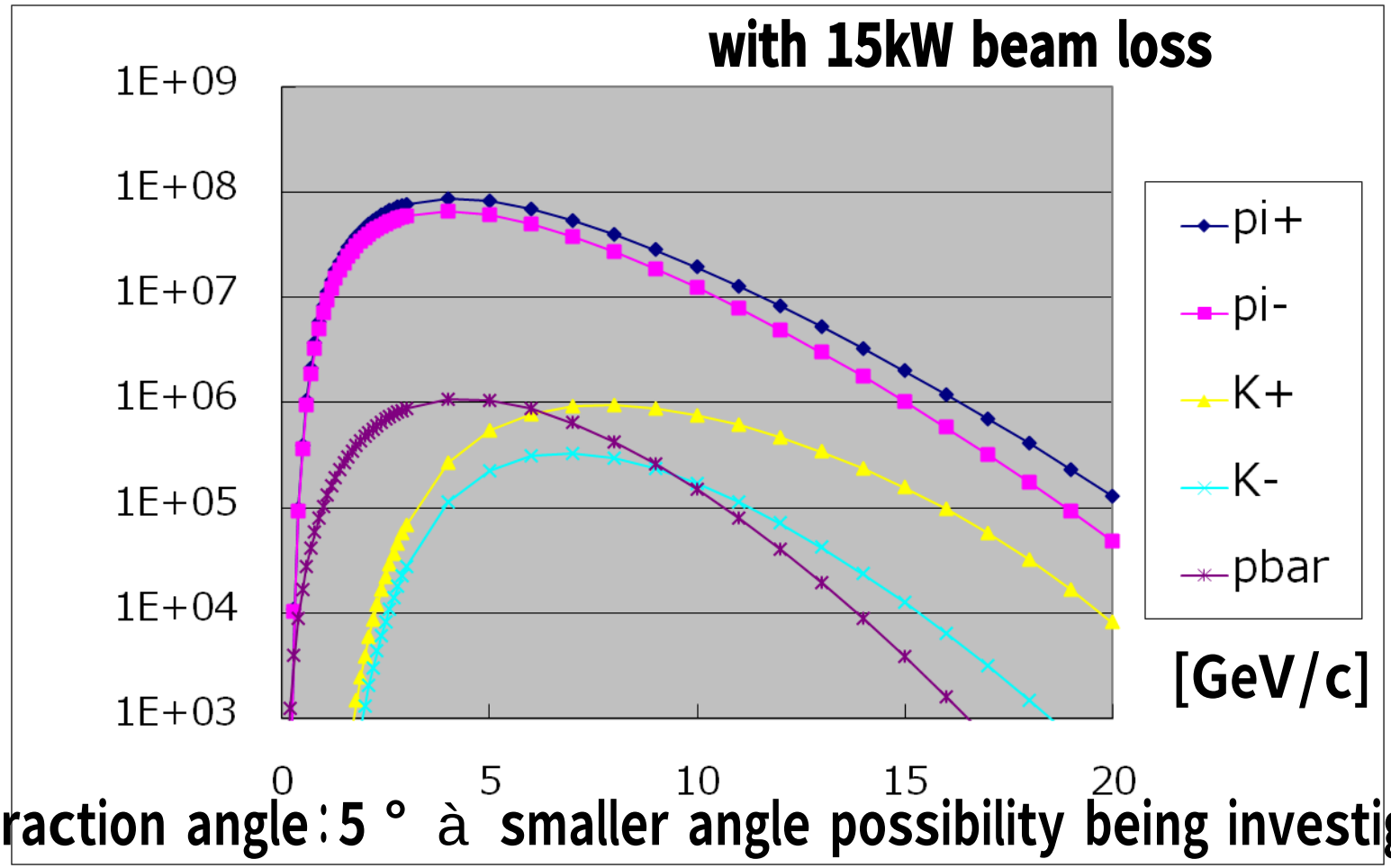
Drell-Yan: $s^{pd}/2s^{pp} \approx [1+\bar{d}(x)/\bar{u}(x)]/2$

J/ψ: $s^{pd}/2s^{pp} \approx [1+g_n(x)/g_p(x)]/2$

Gluon distributions in proton and neutron are very similar at 800 GeV. At much lower energies, J/Psi might be produced by q-qbar annihilation. à Azimuthal angle dependence. If J/Psi production is q-qbar annihilation, J/Psi becomes a tool to investigate quark structure of nucleon at lower energies.

Unseparated Secondary Beam Intensity

beam loss limit @ SM1:15kW
(limited by the thickness of the tunnel wall)

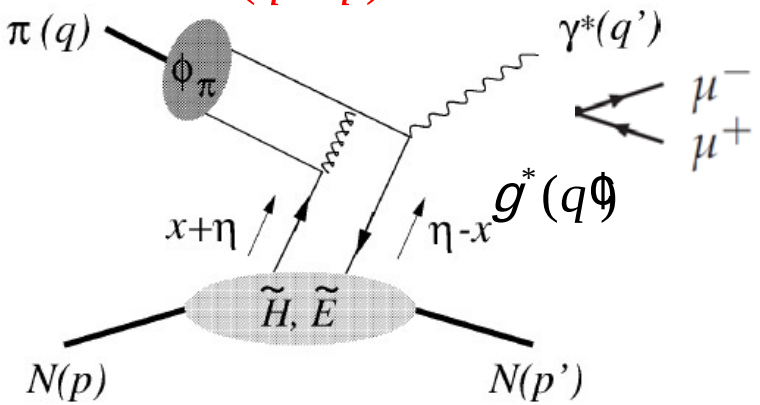


extraction angle：5° à smaller angle possibility being investigated

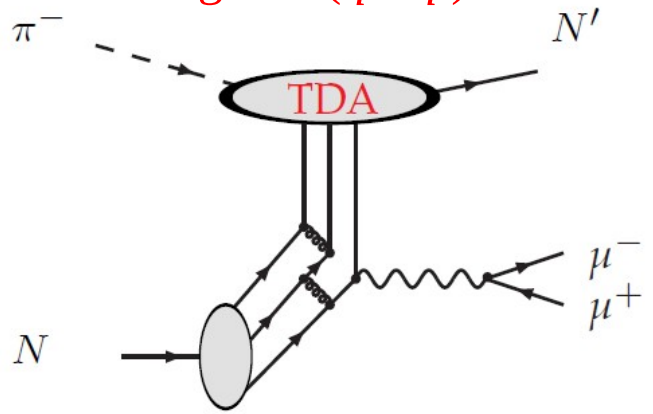
Exclusive Pion-Induced Drell-Yan Process

Bernard Pire , IWHS2011

small $t = (q - q')^2$



large $t = (q - q')^2$



f_p : pion distritribution amplitude (DA)

- **DA characterizes the minimal valence Fock state of hadrons.**
- **DA of pion are also explored by pion-photon transition form factor in Belle and Barbar Exps.**

TDA : p-N transistion distritribution amplitude

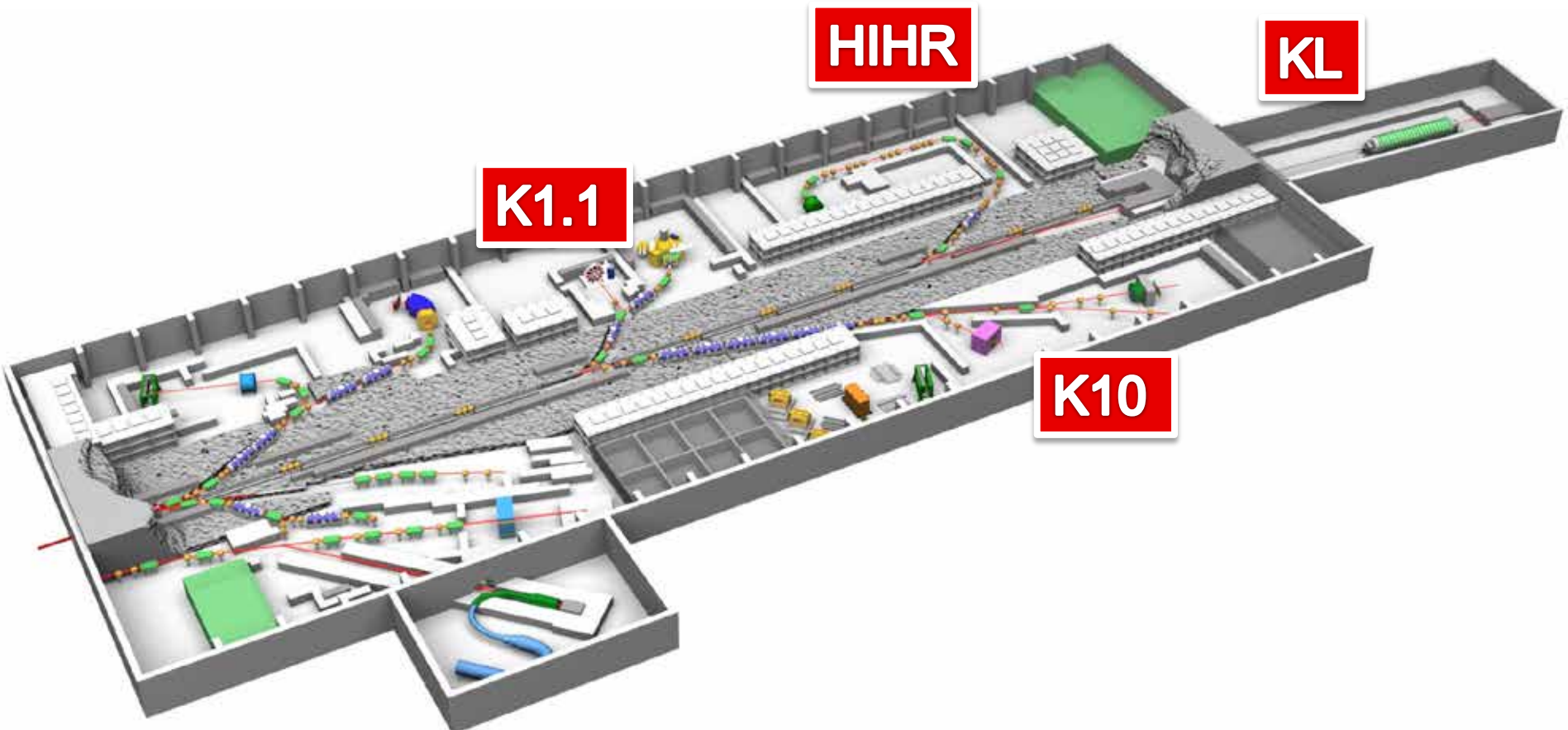
- **TDA characterizes the next-to-minimal valence Fock state of hadrons.**
- **TDA of pion-nucleon is related to the pion cloud of nucleons.**

à **Talk by Wen-Chen**

Contents

Hadron Hall Extension

- Extend the Hadron Hall for ~105m.
- Construct 2 production targets with beam lines.



Hadron Hall Extension

- Hadron Hall extension has been proposed to the Science Council of Japan for their recommendation as a next big project.
- The Institute of Particle and Nuclear Studies, KEK, is starting the discussion for future projects (ILC, neutrino, and Hadron extension) at the research program committee.

- We need a story so that scientists of neighboring fields can understand the importance of the field and the extension!
  - Where we are, and what can be achieved by a new experiment / project?

Summary

- Physics experiments started at the Hadron Hall of J-PARC, and the first physics papers have been published from the E19 and E10 experiments. So far experiments with lower momentum pions/kaons are being carried out.

- The funding for the high-momentum beam line with COMET was approved by the government. The construction starts. Mass shift of phi meson would be the first experiment, and other experiments are being discussed.

- J-PARC is now very busy to respond to the accident. But we certainly renovate the facility to resume research activities in the near future.

- Discussion on the extension is active. In order to convince people of neighboring fields, your help is essential!