J-PARC HADRON PHYSICS PROGRAM

July 22, 2015

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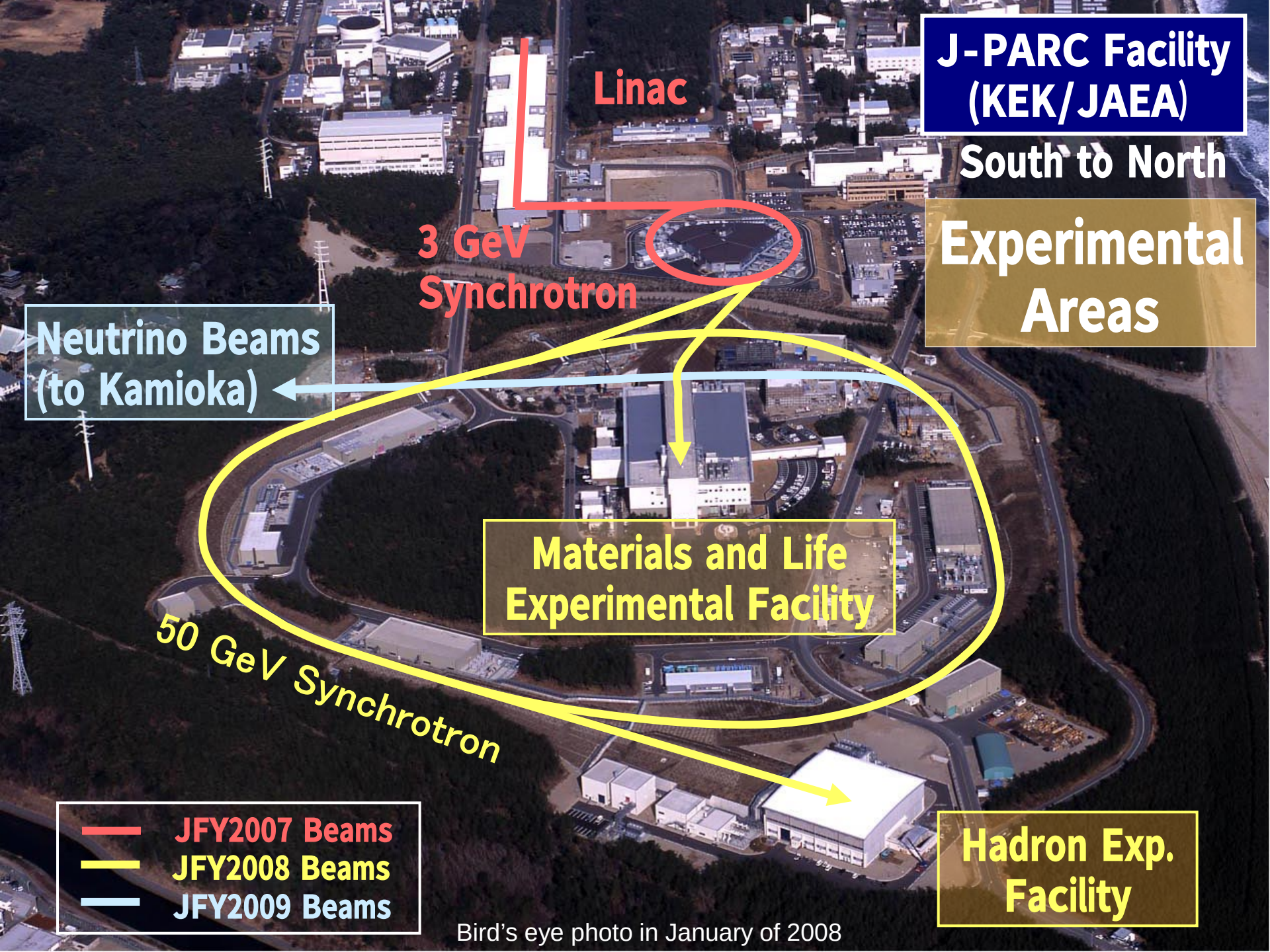
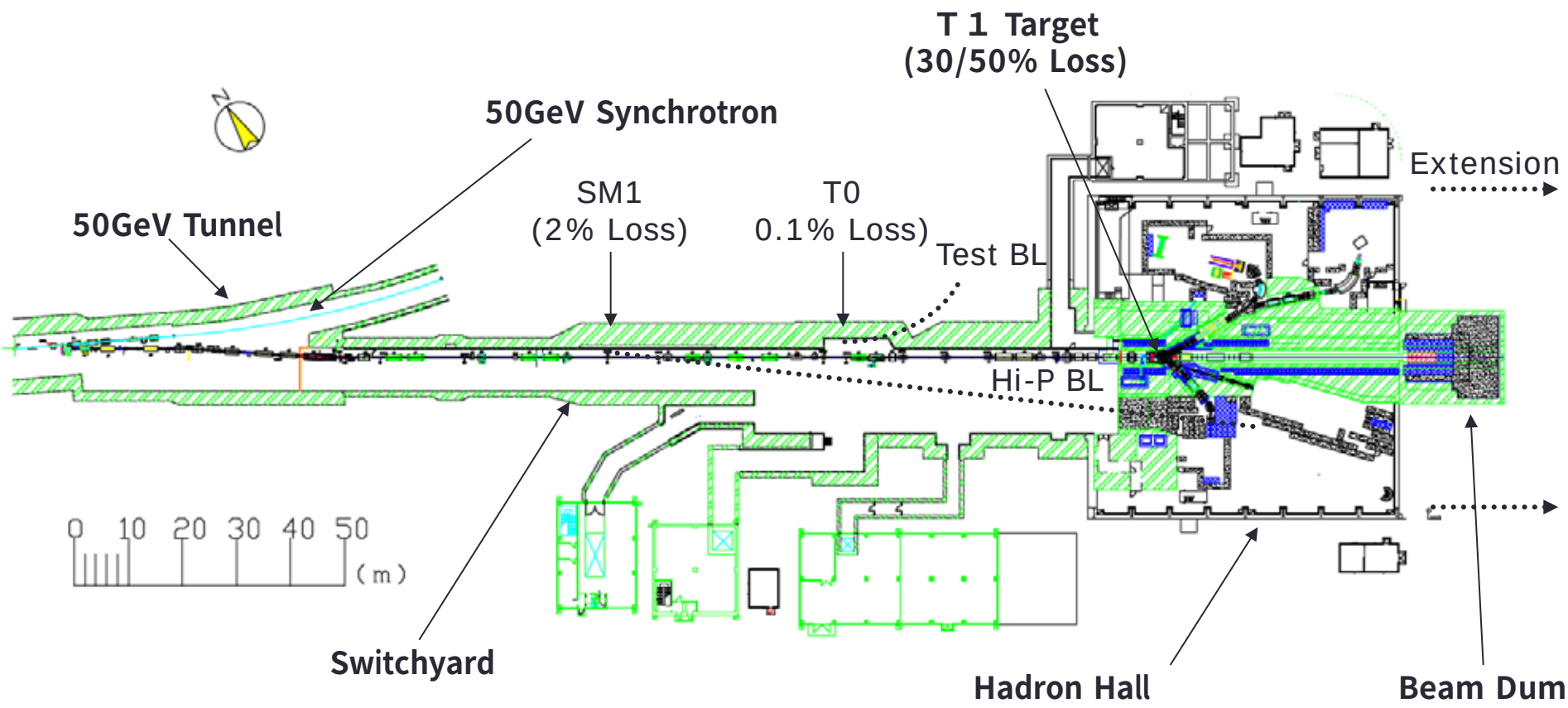
KEK (High Energy Accelerator Research Organization)

Contents


J-PARC Facility
(KEK/JAEA)
South to North
Linac
3 GeV
Synchrotron
Experimental
Areas
Neutrino Beams
(to Kamioka)
Materials and Life
Experimental Facility
50 GeV Synchrotron
JFY2007 Beams
JFY2008 Beams
JFY2009 Beams
Hadron Exp.
Facility
Bird's eye photo in January of 2008

Hadron Experimental Facility (Current Layout)



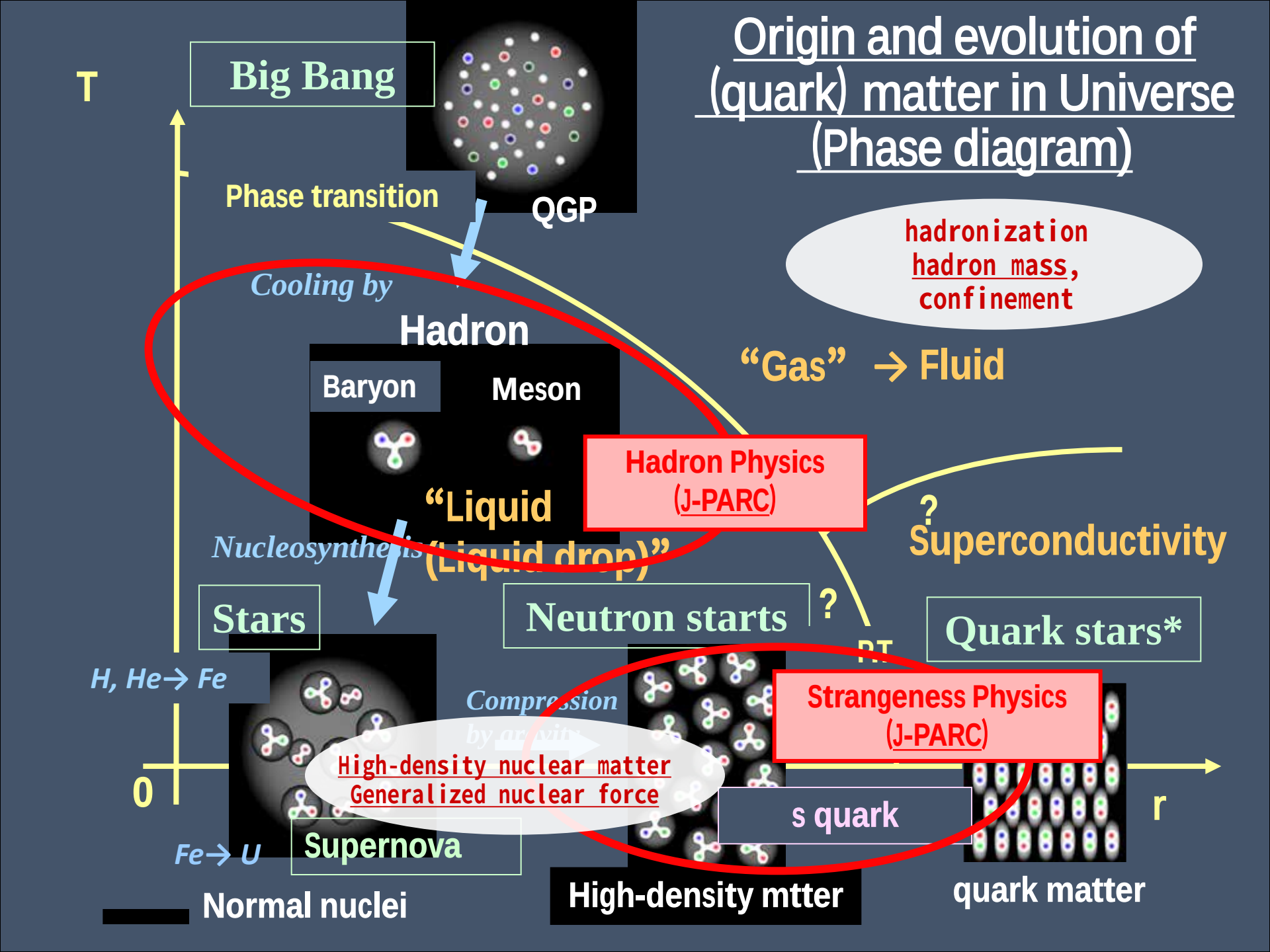
Hadron Experimental Facility (HEF)

Beam Lines	Experiment	Secondary particles	Max. Mom.	Max. Intensity
K1.8	Hypernuclei, Hadron Physics with S	p, K, p (2 separators)	< 2.0 GeV/*c*	~10^5 Hz for K^+
K1.8BR	Hadron Physics with S	p, K, p (1 separator)	< 1.0 GeV/*c*	~10^4 Hz for K^+
K1.1BR	Lepton Flavor violation	p, K, p (1 separator)	< 1.1 GeV/*c*	~10^4 Hz for K^+
KL	Neutral K rare decay	Neural Kaon	~ 2 GeV/*c*	~10^6 Hz

Intense Kaon Beam in the momentum range of ~ 1 GeV/c

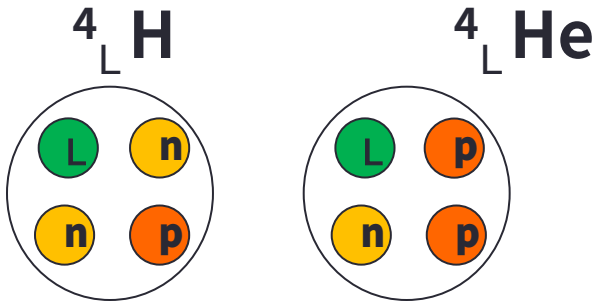
Contents

Origin and evolution of (quark) matter in Universe (Phase diagram)



Nuclear/Hadron Physics at HEF

- Modern picture of nuclear force based on QCD
  - Hypernuclear spectroscopy → YN/YY int. ⇔ lattice-QCD
    - g-ray spectroscopy(E13), double-strangeness system(E03/E05/E07/E42)
  - YN scattering (E40)
- Hadrons in vacuum and medium
  - Exotic hadrons (E19)
  - In-medium property of hadrons
    → Chiral Symmetry Breaking (CSB)
    - meson-mass spectroscopy (E16)
  - L NN three-body force



- Phase diagram and Equation Of State (EOS) of quark (hadron) matter
  - low-T high-r region – Strangeness physics
    - n-rich L -nuclei (E10), multi-strangeness, K^{bar}N interaction (E15/E17/E27/E31)
  - Hadronization phase – Hadron physics
    - exotic hadrons (E19) , charmed baryon spectroscopy (E50)

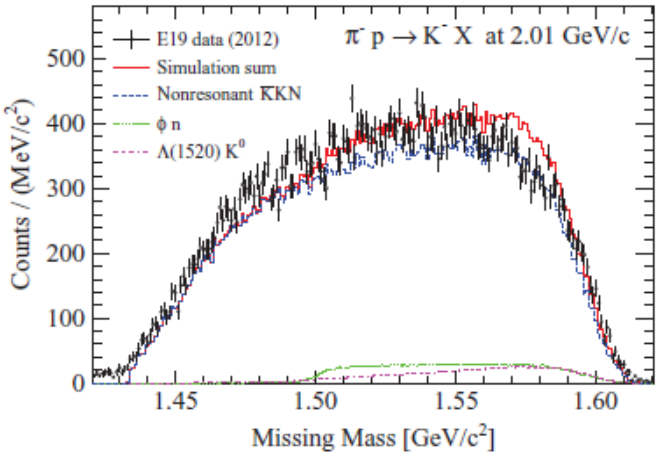
Blue: performed or on-go
Red: plan

Results (1)

- E19:Search for Q^+ by $p^- + p \rightarrow K^- X$
  - No peak was observed
  - U.L. of cross section : 0.28mb/sr
  - U.L. of Q^+ width: 0.36 (1.9) MeV for $\frac{1}{2}^+$ ($\frac{1}{2}^-$)

2010, Jan.2012

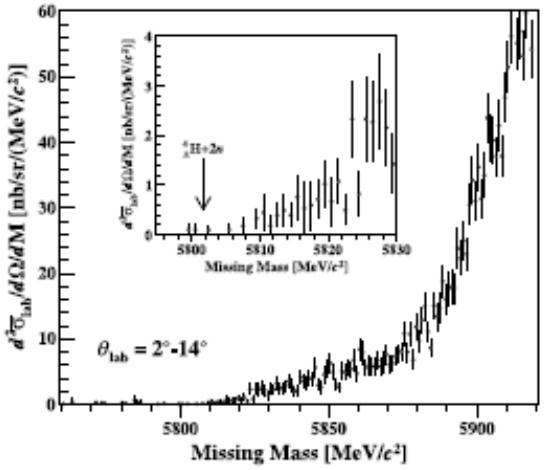
PRL 109, 132002(2012)
PRC 90, 035205(2014)



- E10:Neutron-rich ${}^{6}_{\Lambda}$H via the ^{6}Li(p^-,K^+)
  - No peak was observed
  - U.L. of cross section :1.2nb/sr
  - ⇔ Observation of 3 candidates by FINUDA (PRL **108**,04251(2012))

Dec.2012-Jan.201

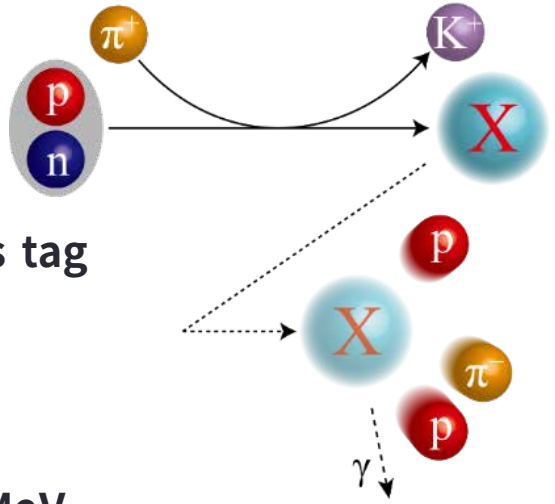
PLB 729, 39 (2014)



Results (2)

- **E27: Search for K^-pp bound states by the $d(p^+,K^+)$ at P_p=1.7GeV/c**

Experimental Method



Jun. 2012

Missing mass spectrum is obtained with two protons tag

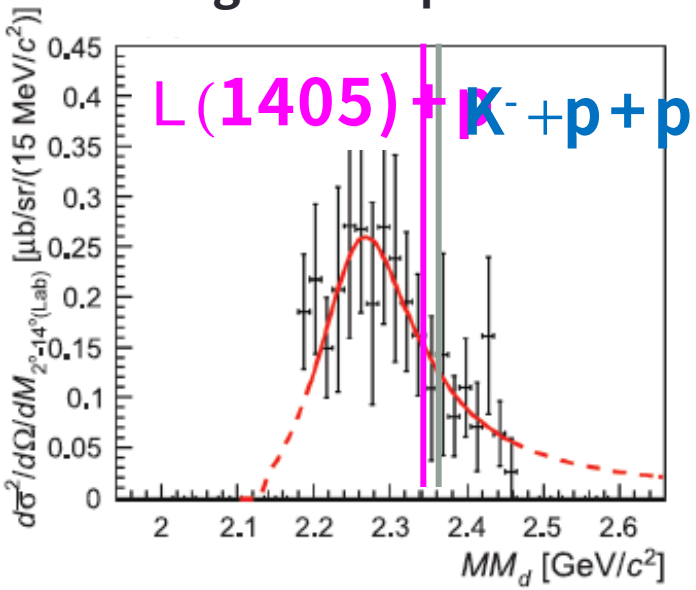
Observation of "K^-pp"-like structure

PTEP 2015, 021D01 (2015)

Binding Energy	95^{+18}_{-17}	(stat.) $^{+30}_{-21}$ (syst.) MeV
Width	162^{+87}_{-45}	(stat.) $^{+66}_{-78}$ (syst.) MeV

A positive signature of K^-pp bound state was obtained. Comparison with other experiments and theoretical studies are necessary and important to establish K^-pp bound state.

Missing mass spectrum



Analysis of inclusive spectrum was also published.

PTEP 2014, 101D03(2014)

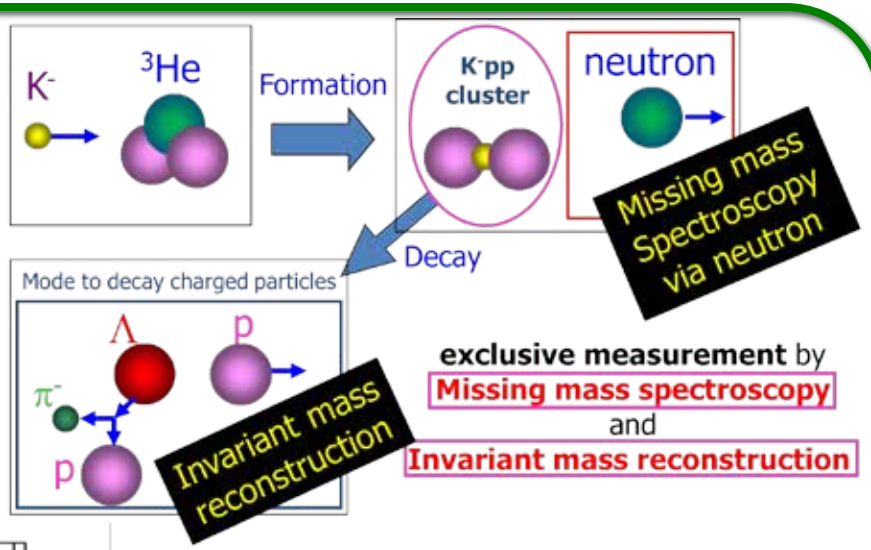
- p SN-L N cusp
- p **Shift of Y* bump**

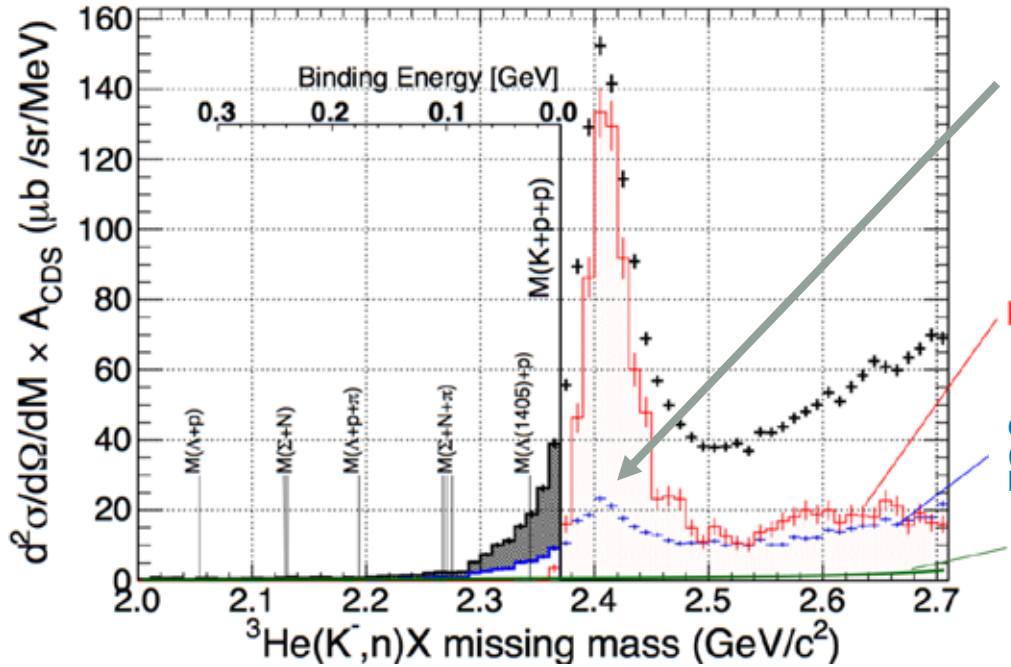
Results (3)

- **E15: Search for K^-pp bound states by the $^3He(K^-,n)X \rightarrow \Lambda p$**

1st- stage RUN with 1% of the proposal

arXiv:1408.5637 [nucl-ex] May 2013





Significant enhancements were observed in a bound-region

"semi"-inclusive
~10MeV/c^2 resolution

K^0_s-tagged x 8

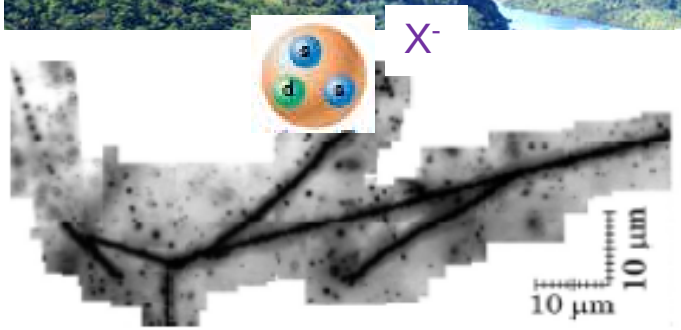
Contribution of S→np
(No other contribution in a bound-region due to kinematical limitations)

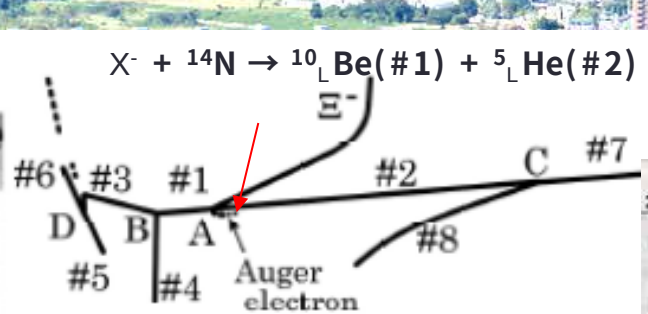
Accidental

Results (4)

In the R&D of E07
Discovery of X-Nucleus for the first time – KISO Event –

In the test application of Overall Scanning Method, which is under R&D for incoming E07 Experiment, to the emulsion sample irradiated before, we found the event in which X^- is deeply bound in ^{14}N. This is the first evidence of X-nucleus





Newspaper (2015/1/19)

Binding energy of X^-

> 1.11±0.25 MeV c.f. 0.17 MeV (atomic orbit)

4.38±0.25MeV if $^{10}_{L}$Be is in ground state.

Attractive XN interaction has been established.

In E07, ~ 100 double-strangeness events will be observed.

⇒ detailed information on S=-2 interaction

Plan and prospects

We have almost finished the renovation work from the radiation incident on May, 2013, and just restarting the beam operation soon.

- In 2015
  - γ-ray spectroscopy of $^{4}_{\Lambda}$He and $^{19}_{\Lambda}$F (E13@K1.8)
    - Charge Symmetry Breaking of 4-body hypernuclei
    - ΛN spin-spin interaction in *sd*-shell hypernucleus
      ⇔ radial dependence of the interaction

YN int. (in medium) EOS

  - K^-pp search by both missing-mass and invariant-mass (E15@K1.8BR)
    - comparison with E27 results
    - Some conclusion of K^-pp bound system

$K^{bar}N$ int.⇒EOS

- 2016 –
  - Study of double strangeness system at K1.8 using KURAMA/S-2S
    - Emulsion exp. (E07) 100 ΛΛ hypernuclei, X-nuclei
    - Energy shift of X-ray from X- atom (E03)
    - Spectroscopy of X-hypernuclei (E05) $^{12}_{X}$Be
    - Search for H-dibaryon (E42)

ΛΛ and XN interaction

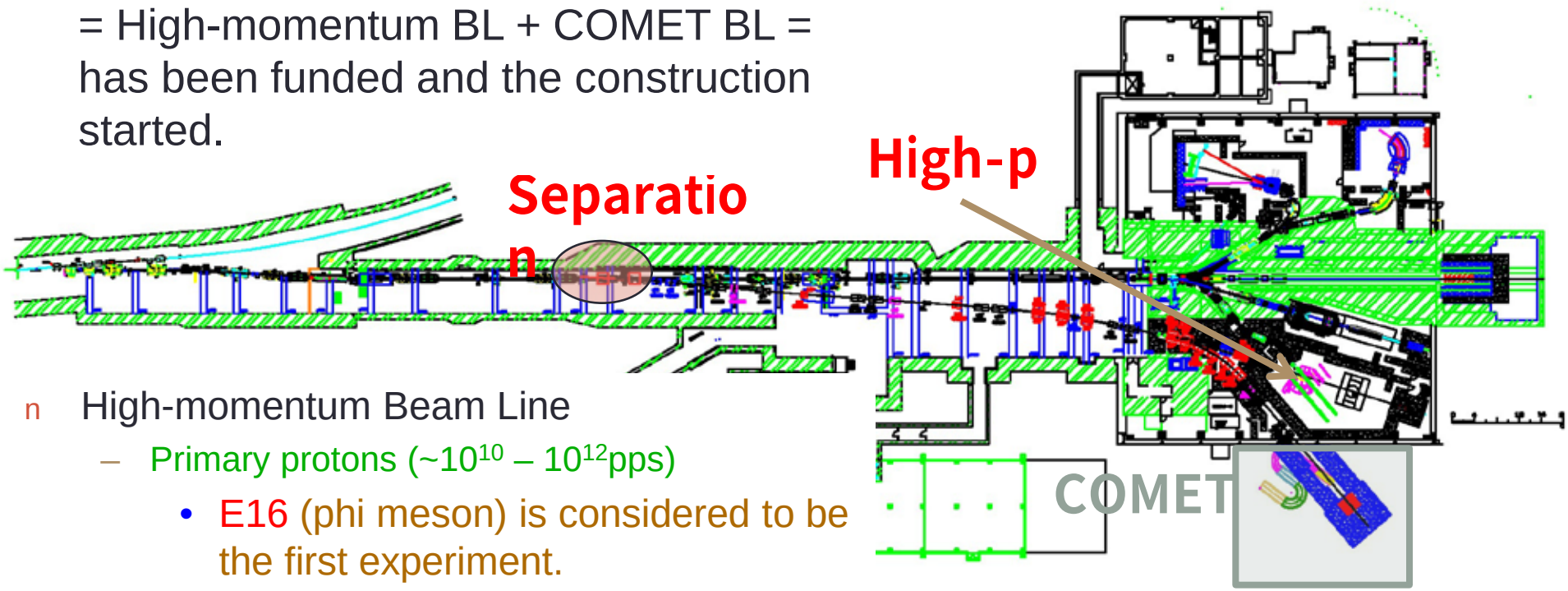
  - Detailed study of $K^{bar}N$ interaction / Λ(1405) at K1.8BR(E31)

$K^{bar}N$ int.⇒EOS

Contents

New Primary Proton Beam Line

- New primary Proton Beam Line
  = High-momentum BL + COMET BL =
  has been funded and the construction started.



- 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.

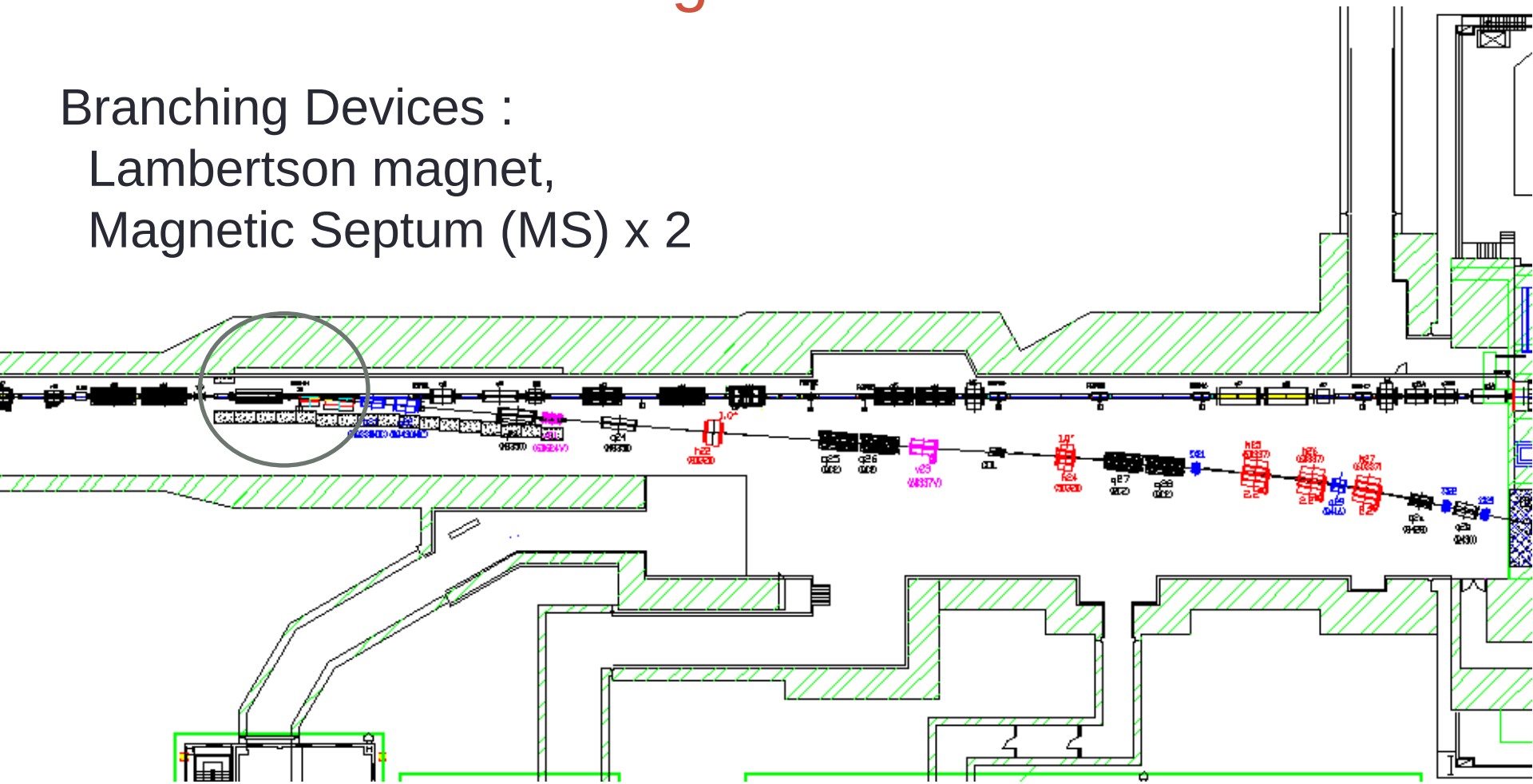
- COMET
  - Search for mto e conversion
  - 8 GeV, 50 kW protons
  - Branch from the high-momentum BL
  - Annex building is being built at the south side.

Status of Beamline Magnets

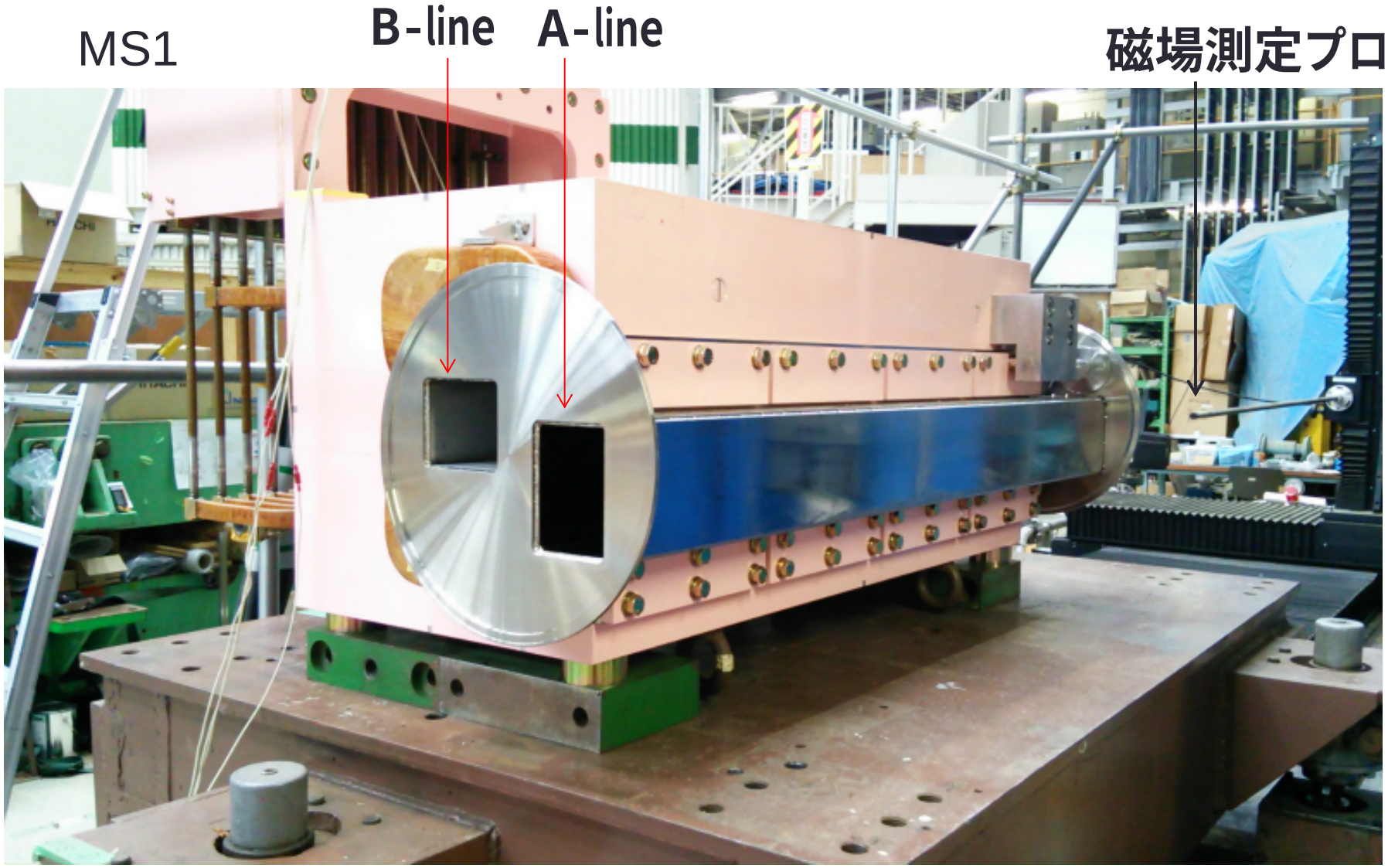
Branching Devices :

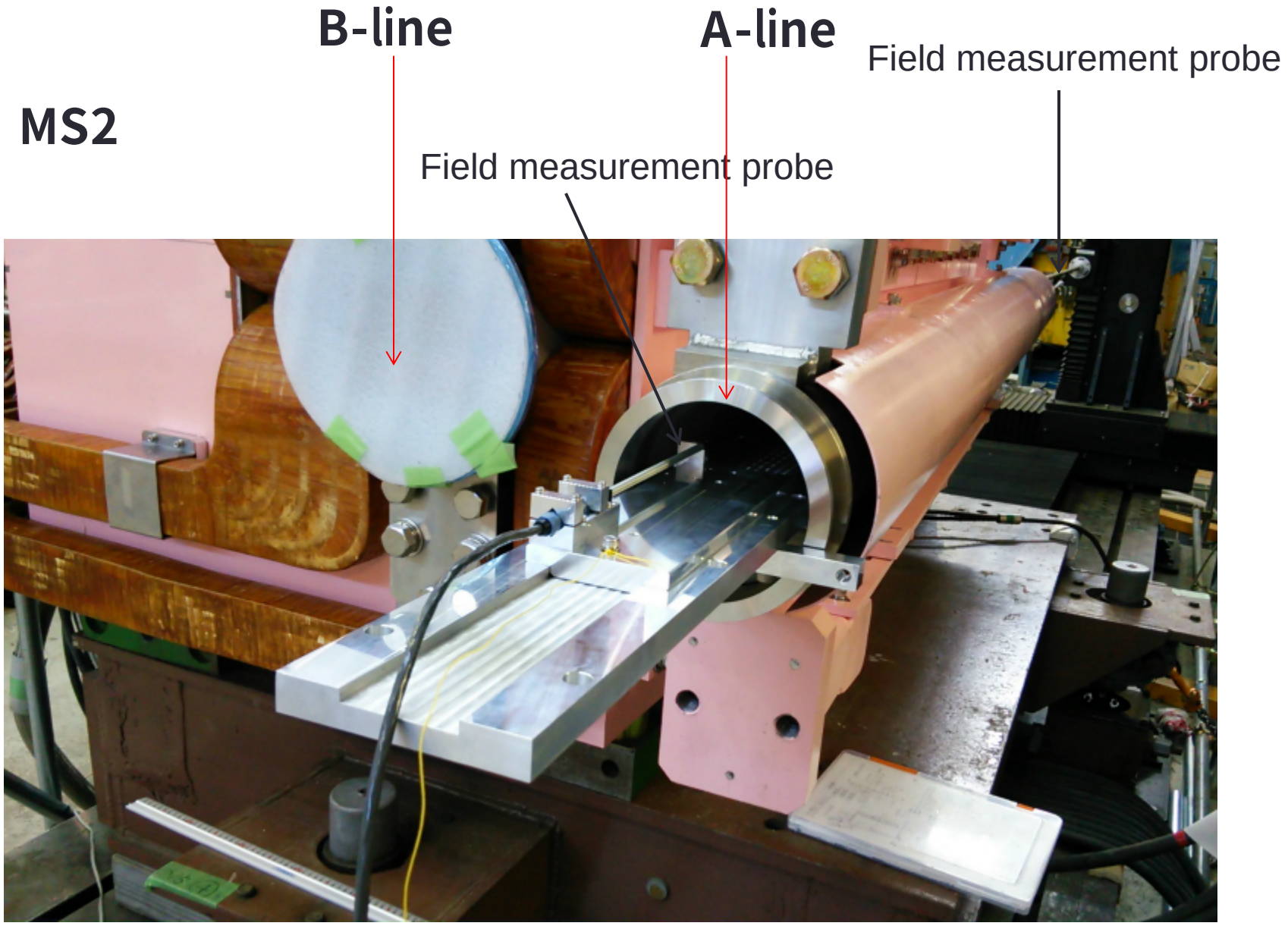
Lambertson magnet,

Magnetic Septum (MS) x 2



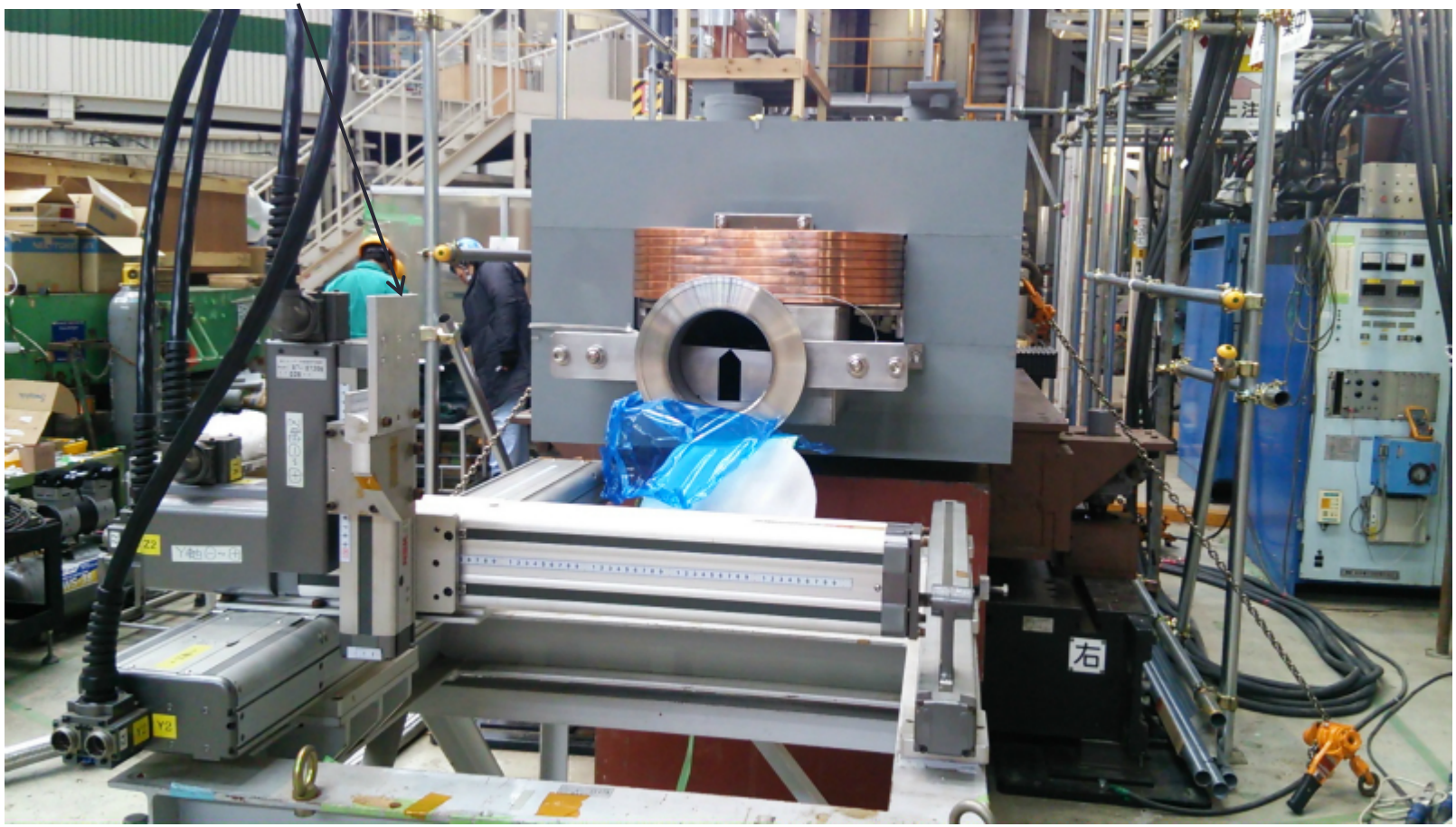
Branching devices: field measurement underway



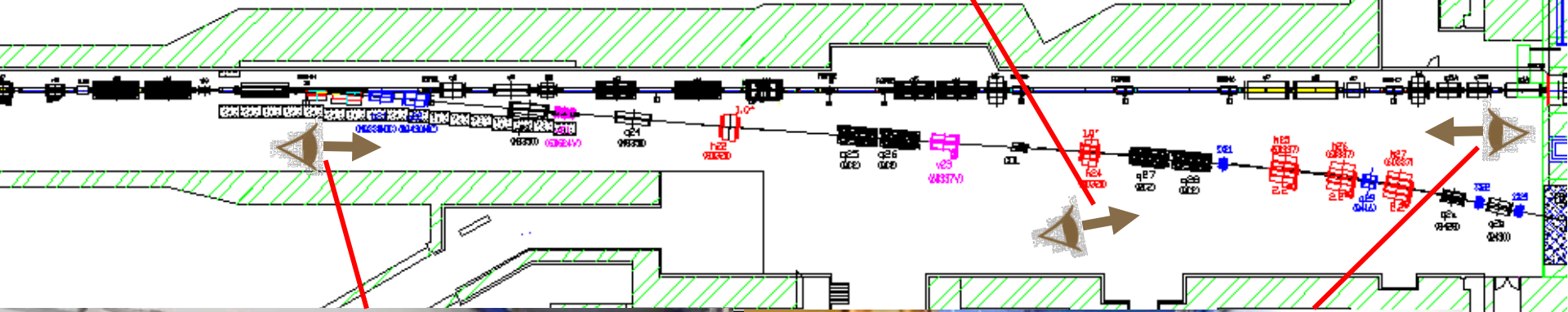

B-line
A-line
Field measurement probe
MS2
Field measurement probe

Lambertson

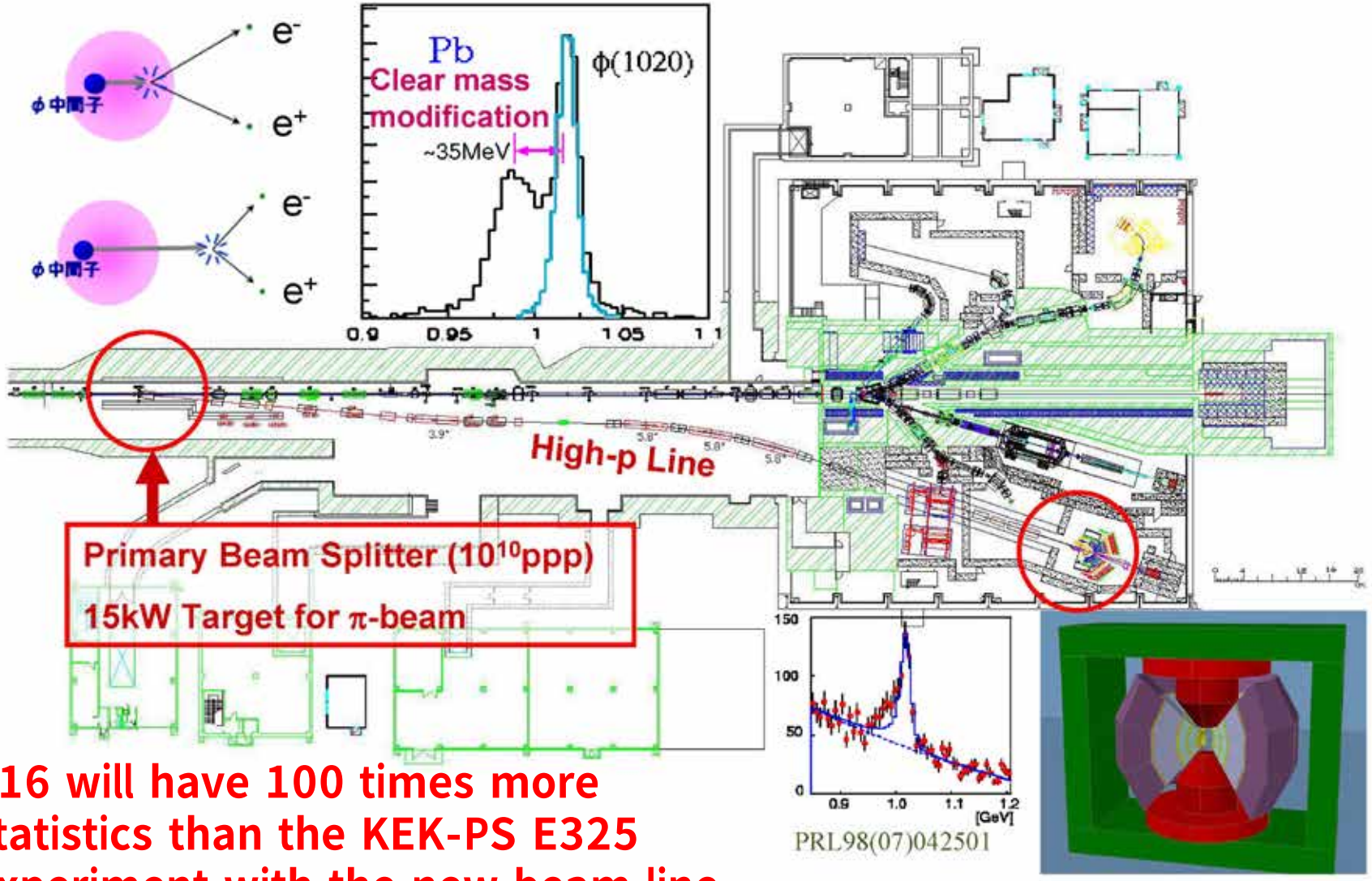
磁場測定用3軸架台



Beam Line Magnets in SY :
Construction & Alignment are completed



High-p Line and E16 Spectrometer

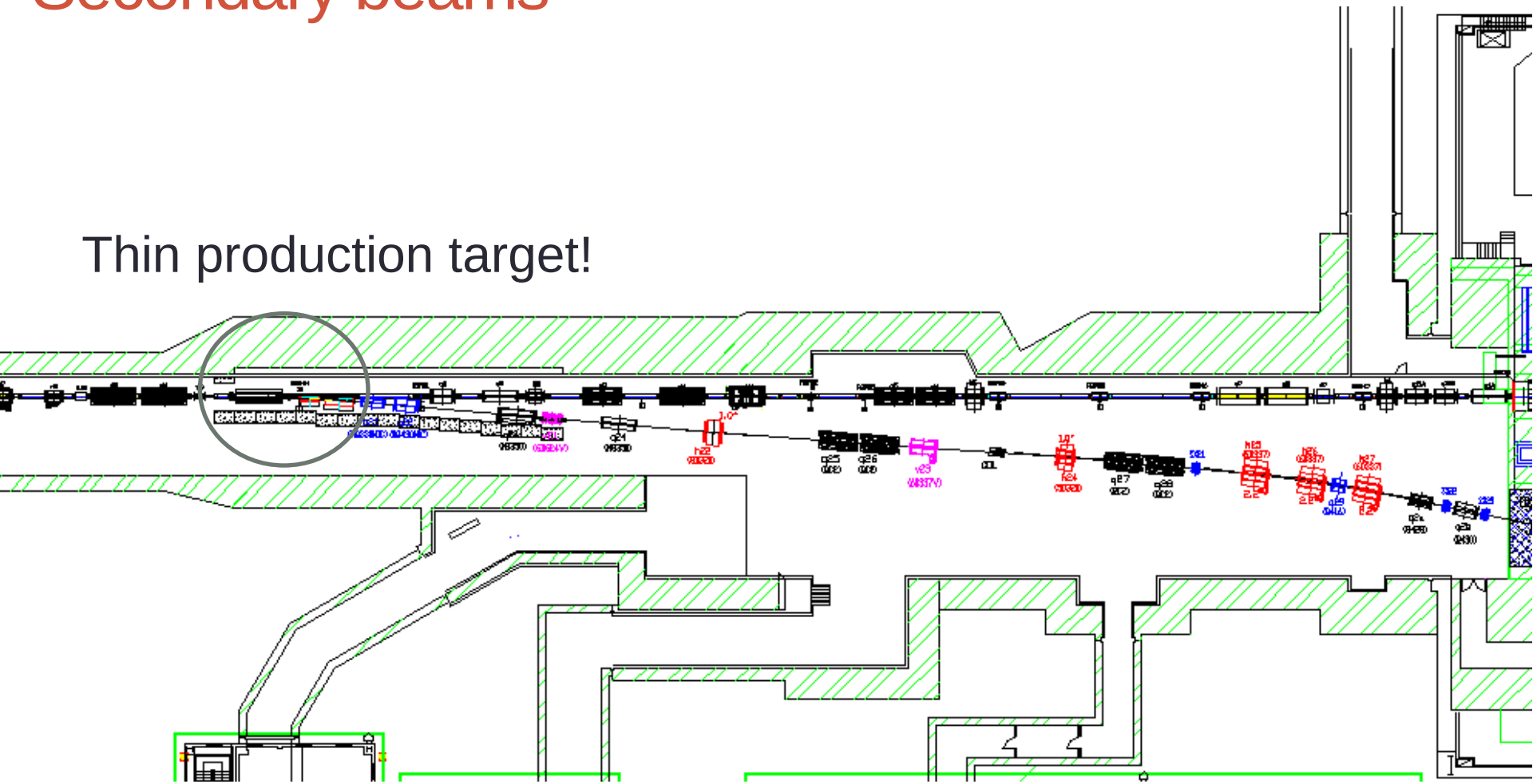


E16 will have 100 times more statistics than the KEK-PS E325 experiment with the new beam line and the spectrometer

Large spectrometer magnet being installed at the right position on the beam line

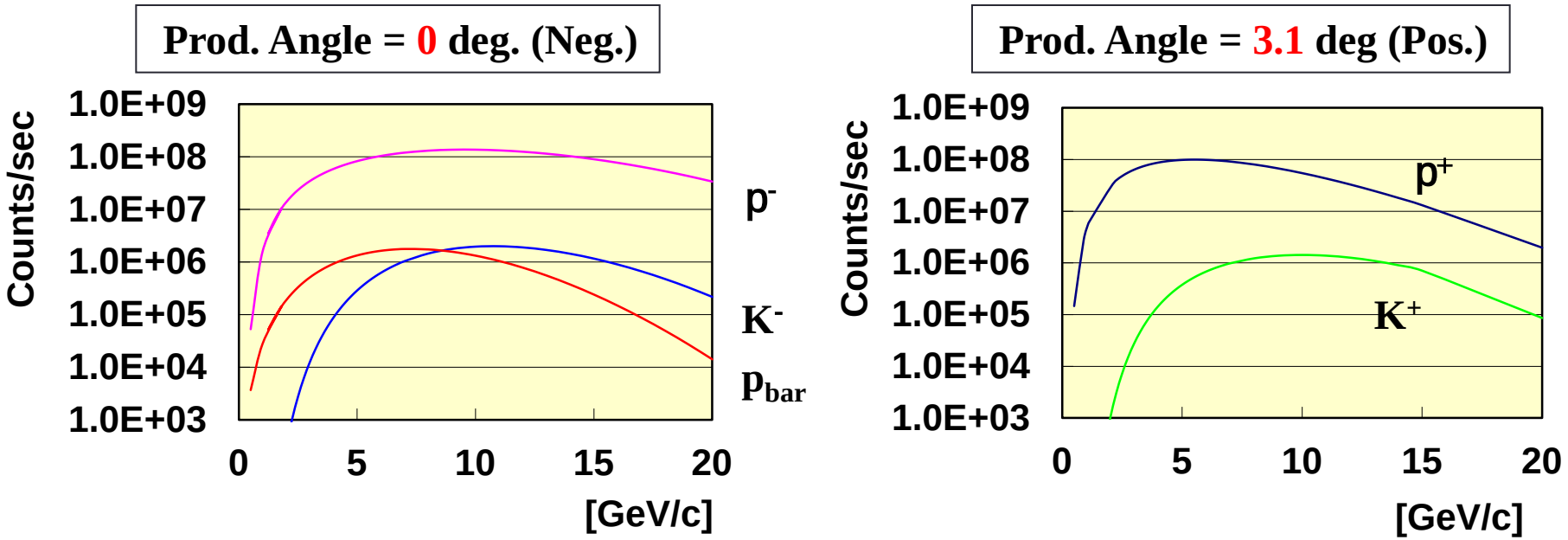
Secondary beams

Thin production target!



Unseparated Secondary Beam

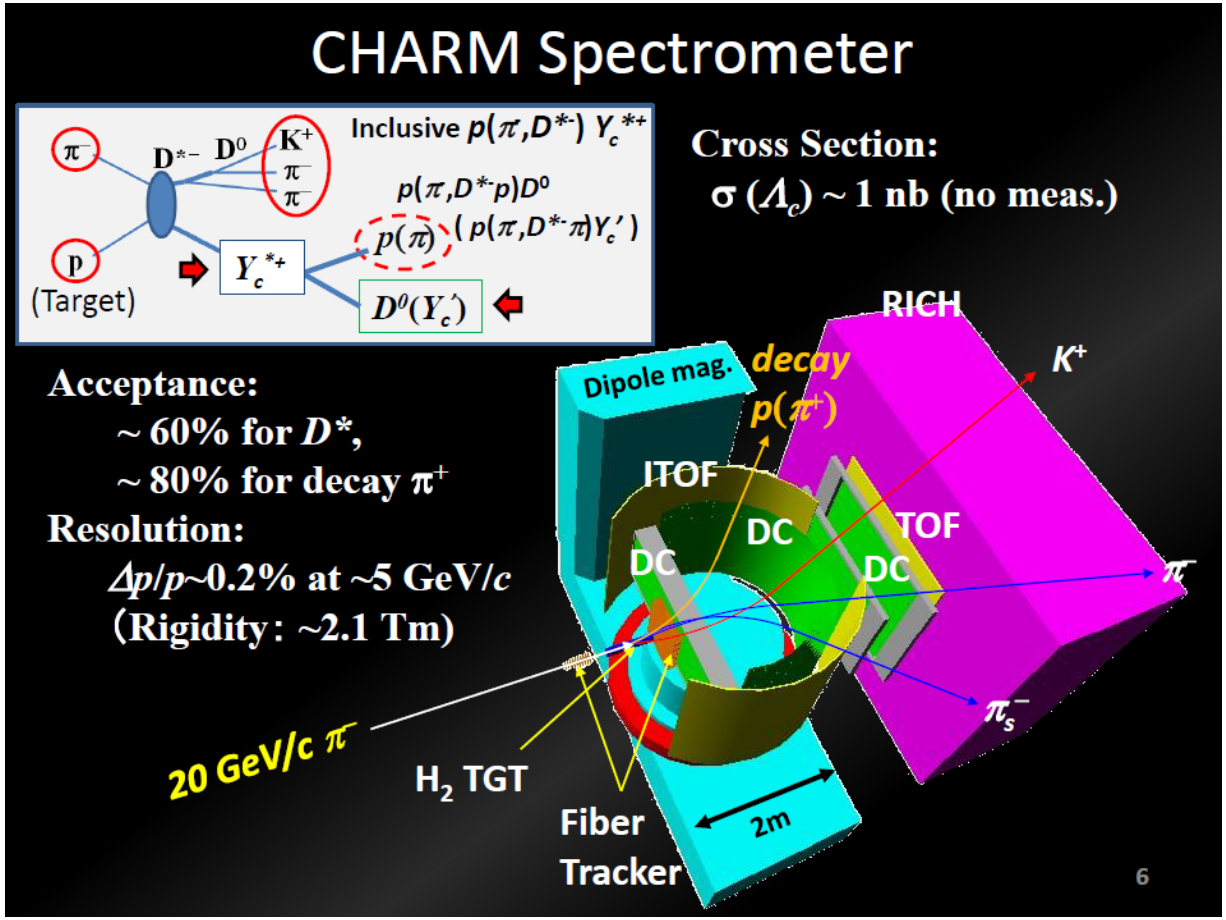
Noumi



* Sanford-Wang:15 kW Loss on Pt, Acceptance :1.5 msr%, 133.2 m

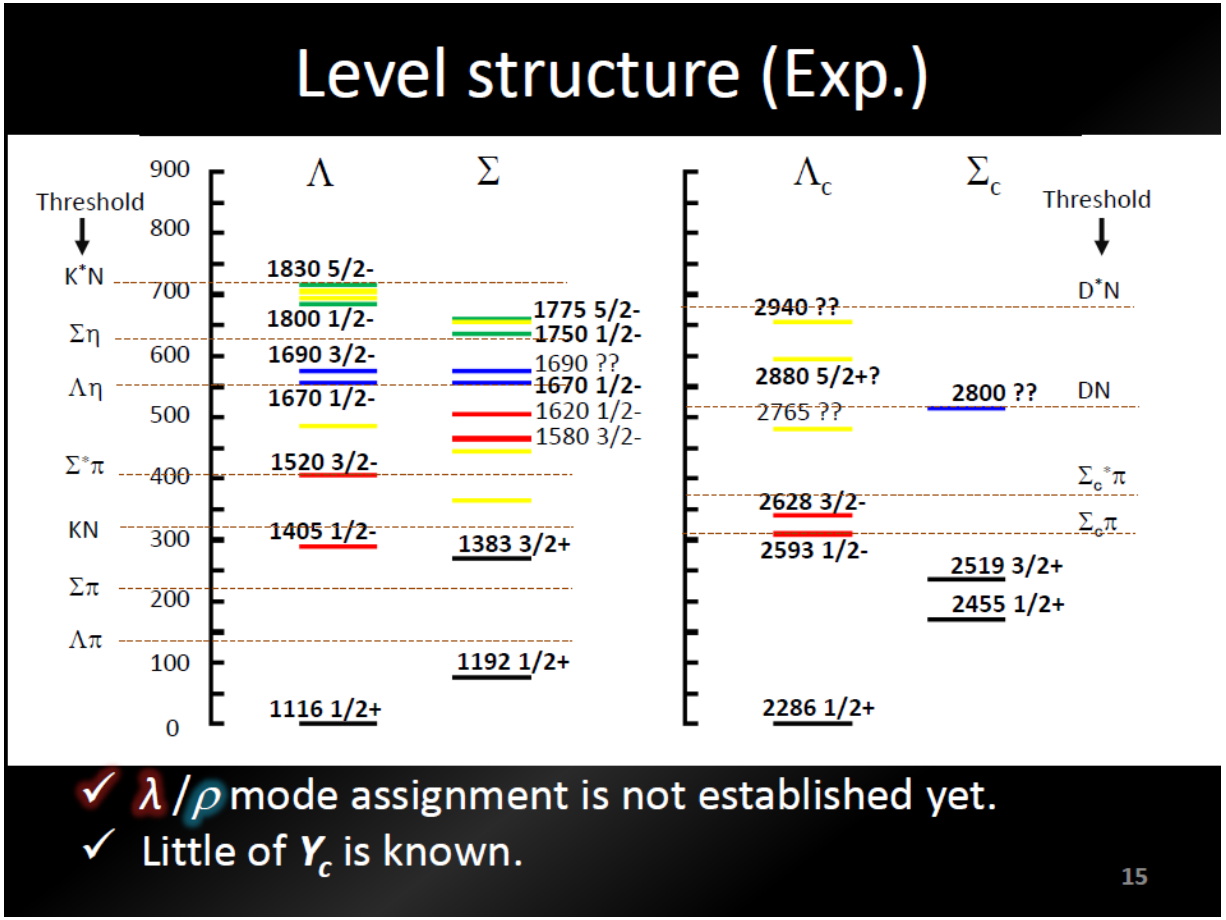
J-PARC E50

Stage-1 approved by J-PARC PAC-18, August 12, 2014.



H. Noumi, KEK workshop 2015

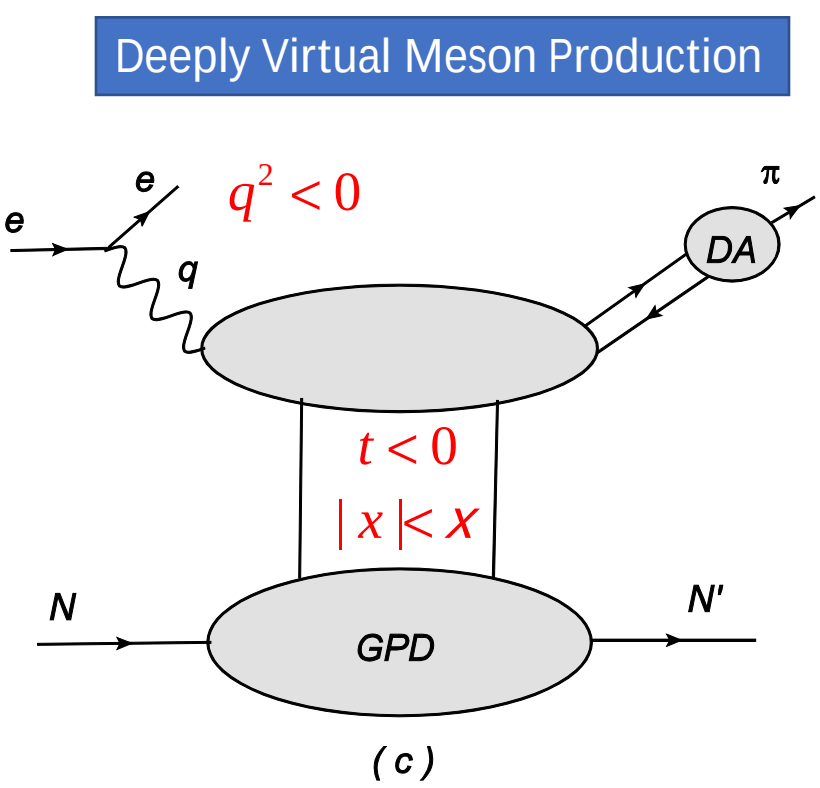
Charmed Baryon Spectroscopy

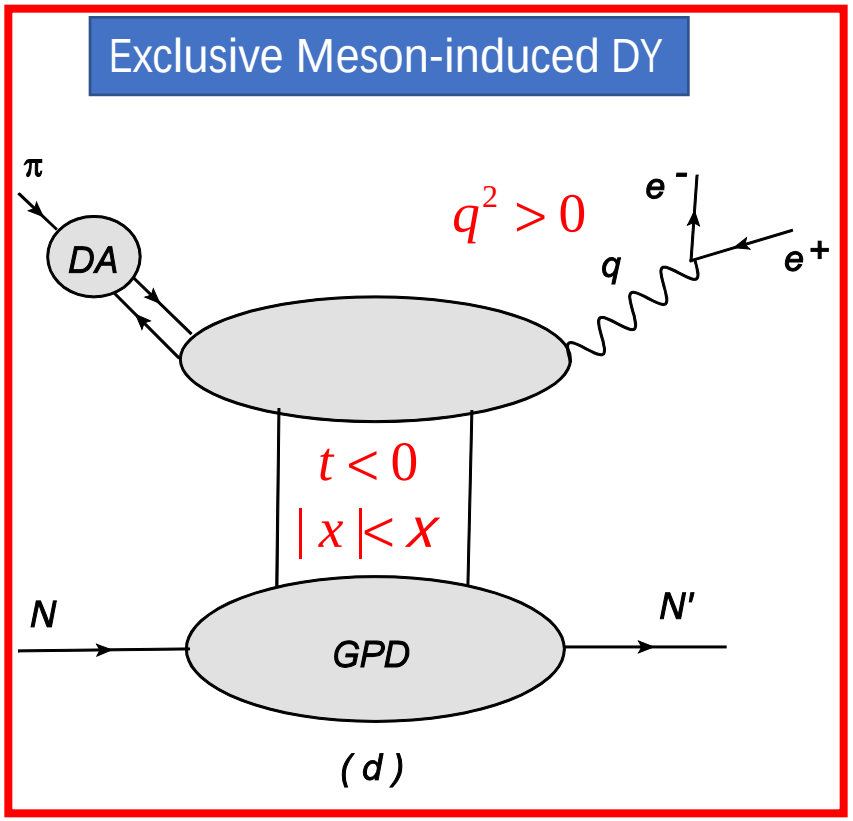


H. Noumi, KEK workshop 2015

Measurement of GPDs: Spacelike vs. Timelike Processes

Muller et al., PRD 86 031502(R) (2012)



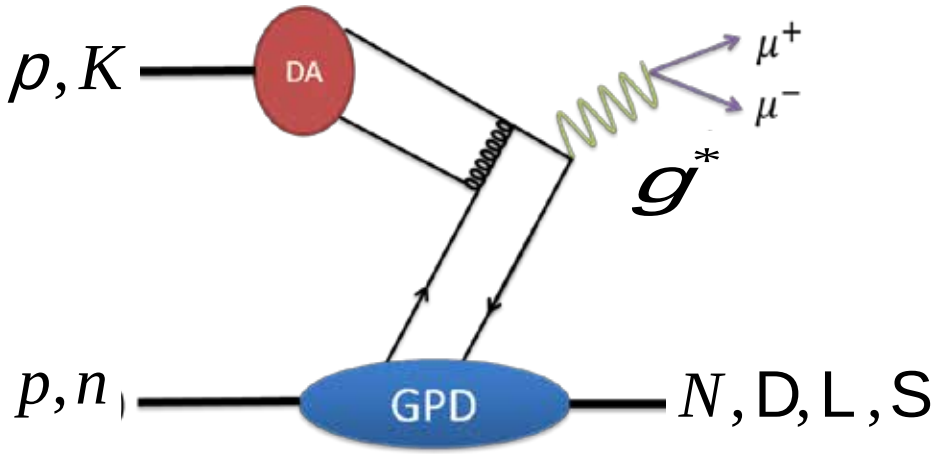


To be measured with hadron beams.

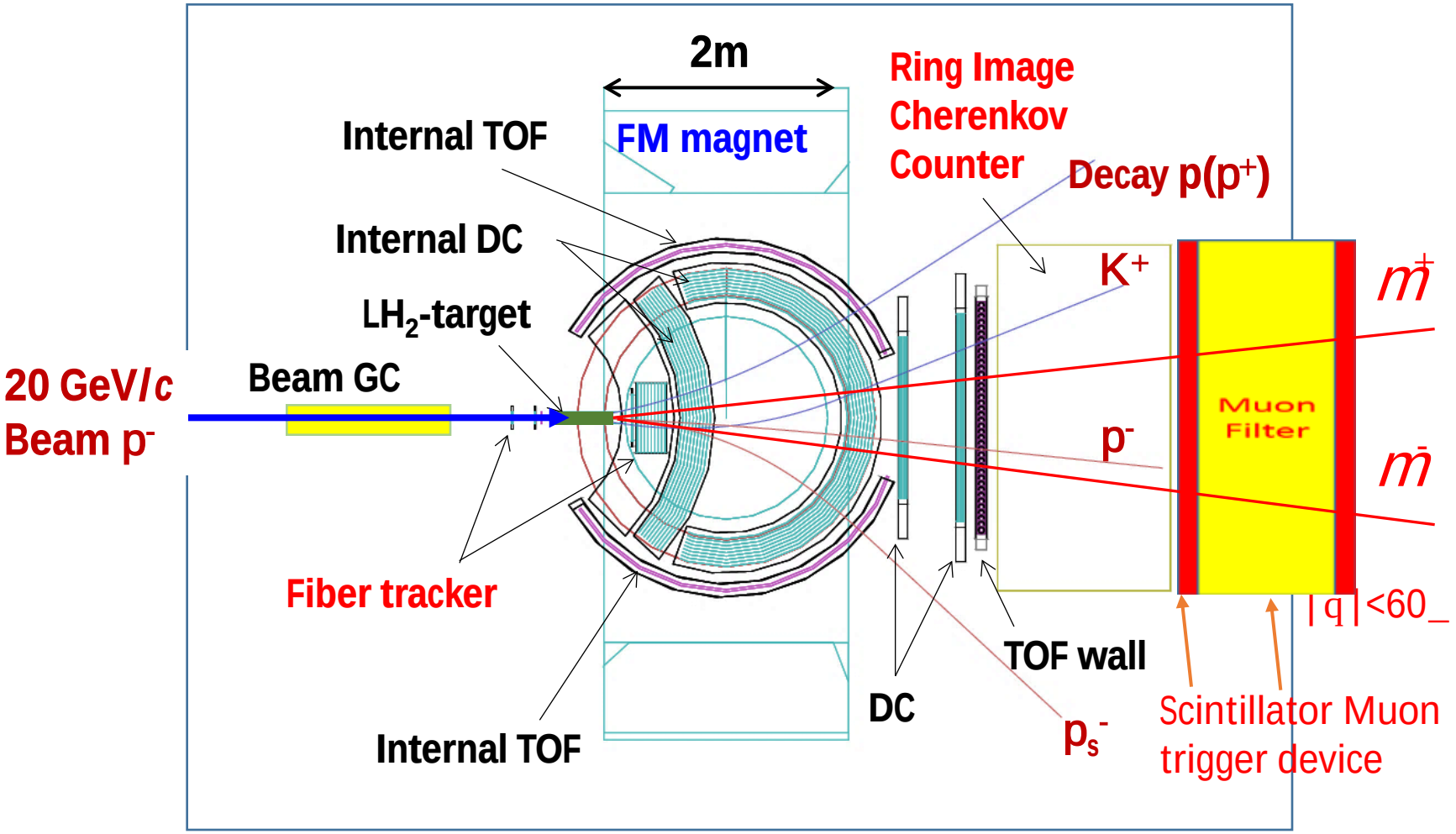
“GPD” and “Transition GPD”

- $\pi^- \mathrm{p} \rightarrow \gamma^* n$
- $\pi^- \mathrm{p} \rightarrow \gamma^* \Delta^0$
- $\pi^- \mathrm{n} \rightarrow \gamma^* \Delta^-$
- $\pi^+ \mathrm{n} \rightarrow \gamma^* \mathrm{p}$
- $\pi^+ \mathrm{p} \rightarrow \gamma^* \Delta^{++}$
- $\pi^+ \mathrm{n} \rightarrow \gamma^* \Delta^+$

- $K^- \mathrm{p} \rightarrow \gamma^* \Lambda$
- $K^- \mathrm{p} \rightarrow \gamma^* \Lambda(1405)$
- $K^- \mathrm{p} \rightarrow \gamma^* \Lambda(1520)$
- $K^- \mathrm{n} \rightarrow \gamma^* \Sigma^-$



J-PARC E50 Spectrometer + MuID



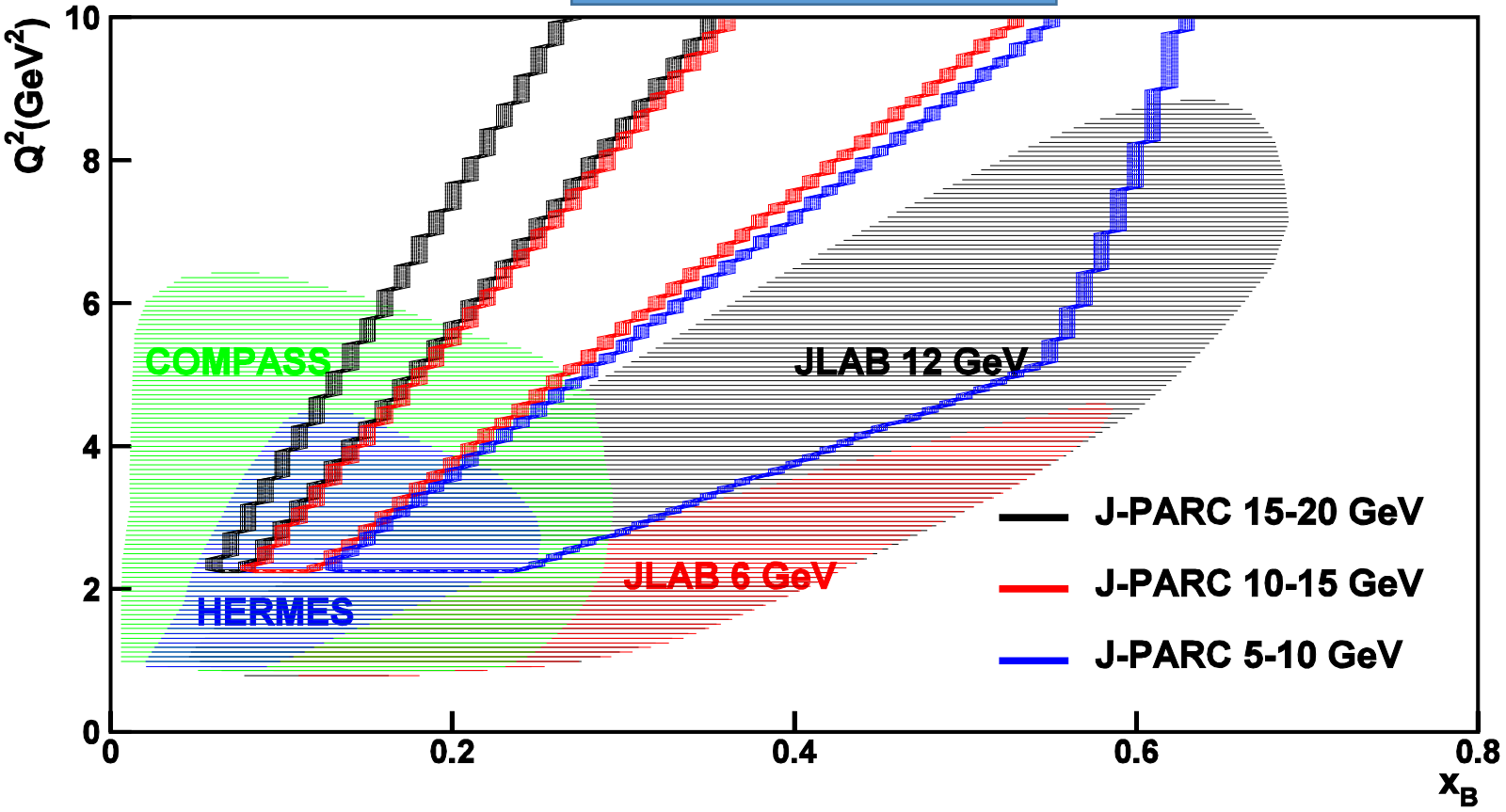
Acceptance: ~ 60% for D^*, ~80% for decay p^+

Resolution: $\Delta p/p$~0.2% at ~5 GeV/c (Rigidity: ~2.1 Tm)

See Takahiro Sawada's Talk!

GPD(x_B,t;Q^2) from space-like and time-like processes

Large-Q^2 region



- J-PARC: **time-like** approach and **large-Q^2** region.

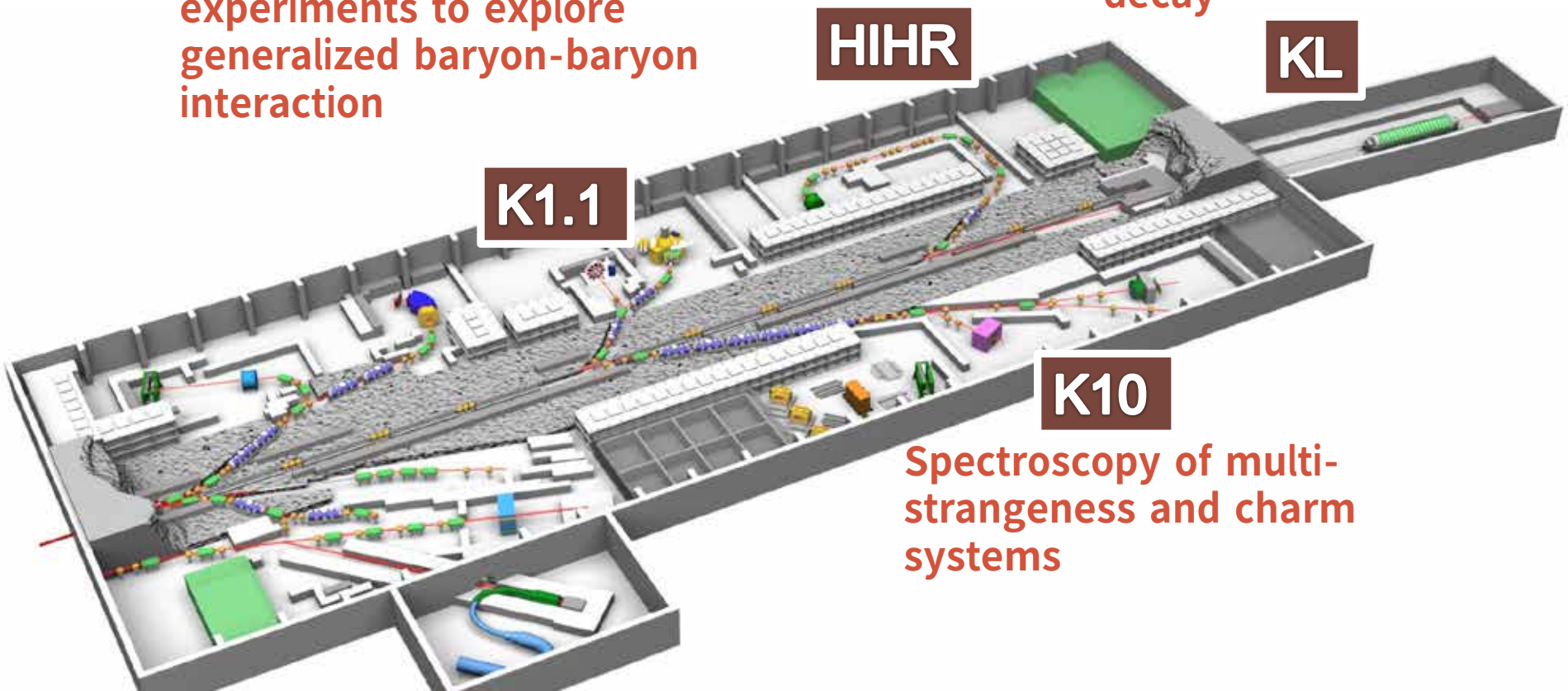
Contents

Hadron Hall Extension

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

Single strangeness experiments to explore generalized baryon-baryon interaction

From discovery to measurement of K0 rare decay



Spectroscopy of multi-strangeness and charm systems

Hadron Hall Extension

- Hadron Hall extension has been proposed to the Science Council of Japan for their recommendation as a next big project, and selected as one of the 27 important big projects.
- The Institute of Particle and Nuclear Studies, KEK has made the discussion for future projects (ILC, neutrino, and Hadron extension) at the research program committee, and they have concluded that the Hadron extension should be promoted, as well as other projects.

Summary

- Physics experiments started at the Hadron Hall of J-PARC, and the first physics papers have been published from experiments.
- The funding for the high-momentum beam line with COMET was approved by the government. The construction started. Mass shift of phi meson would be the first experiment, and other experiments are being discussed.
- The Hadron Facility restarted after the May, 2013 incident. More fruits come soon.
- Discussion on the extension is active. Your ideas are welcome.