J-PARC HADRON PHYSICS PROGRAM

March 2, 2016

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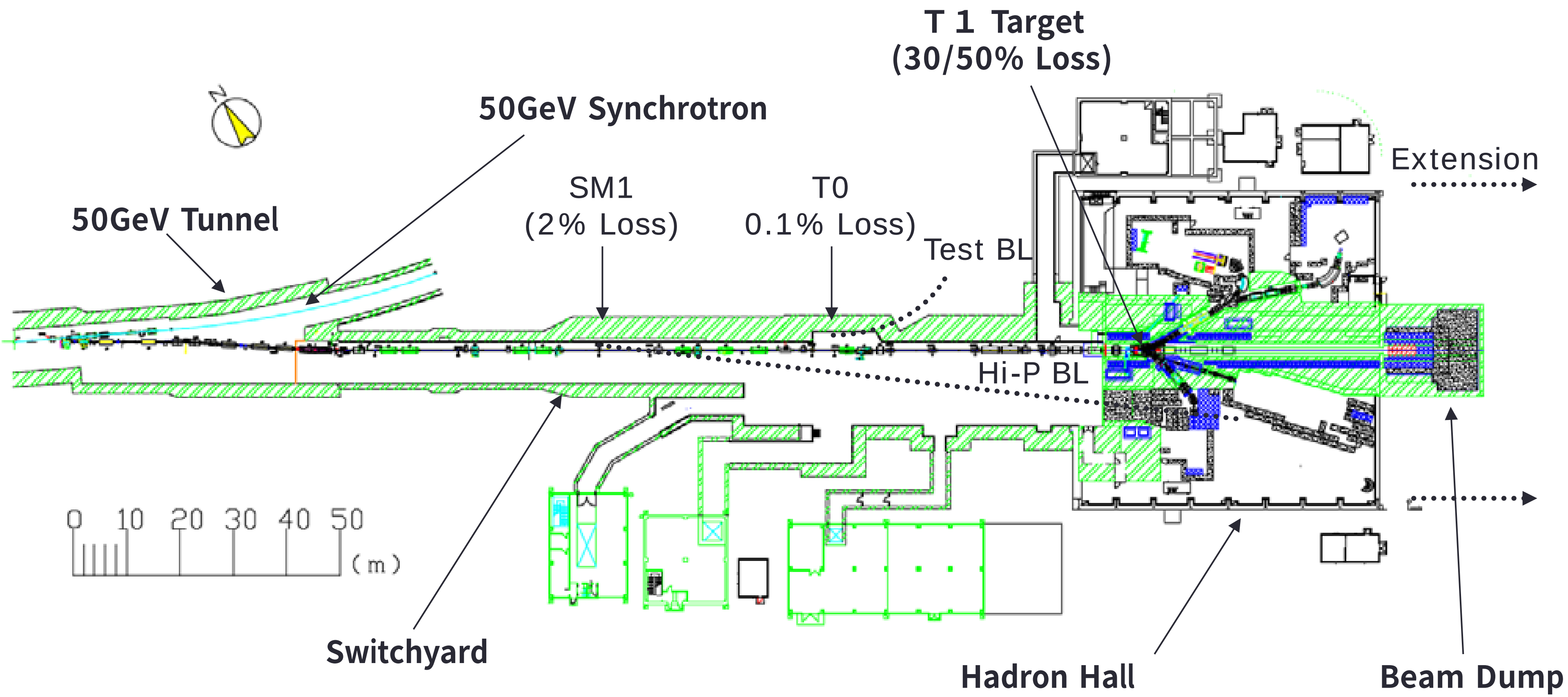
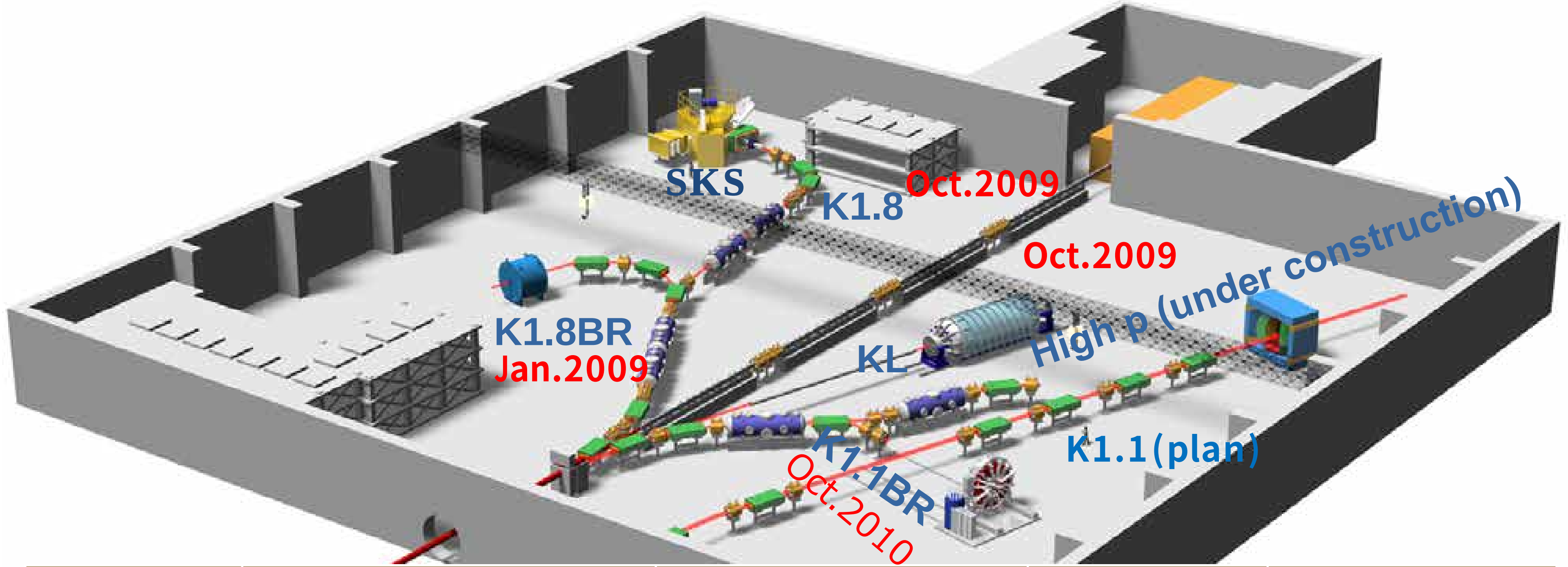
Contents


J-PARC Facility
(KEK/JAEA)
South to North
Experimental
Areas
Linac
3 GeV
Synchrotron
Neutrino Beams
(to Kamioka)
Materials and Life
Experimental Facility
50 GeV Synchrotron
Hadron Exp.
Facility
JFY2007 Beams
JFY2008 Beams
JFY2009 Beams
Bird's eye photo in January of 2016

Hadron Experimental Facility (Current Layout)



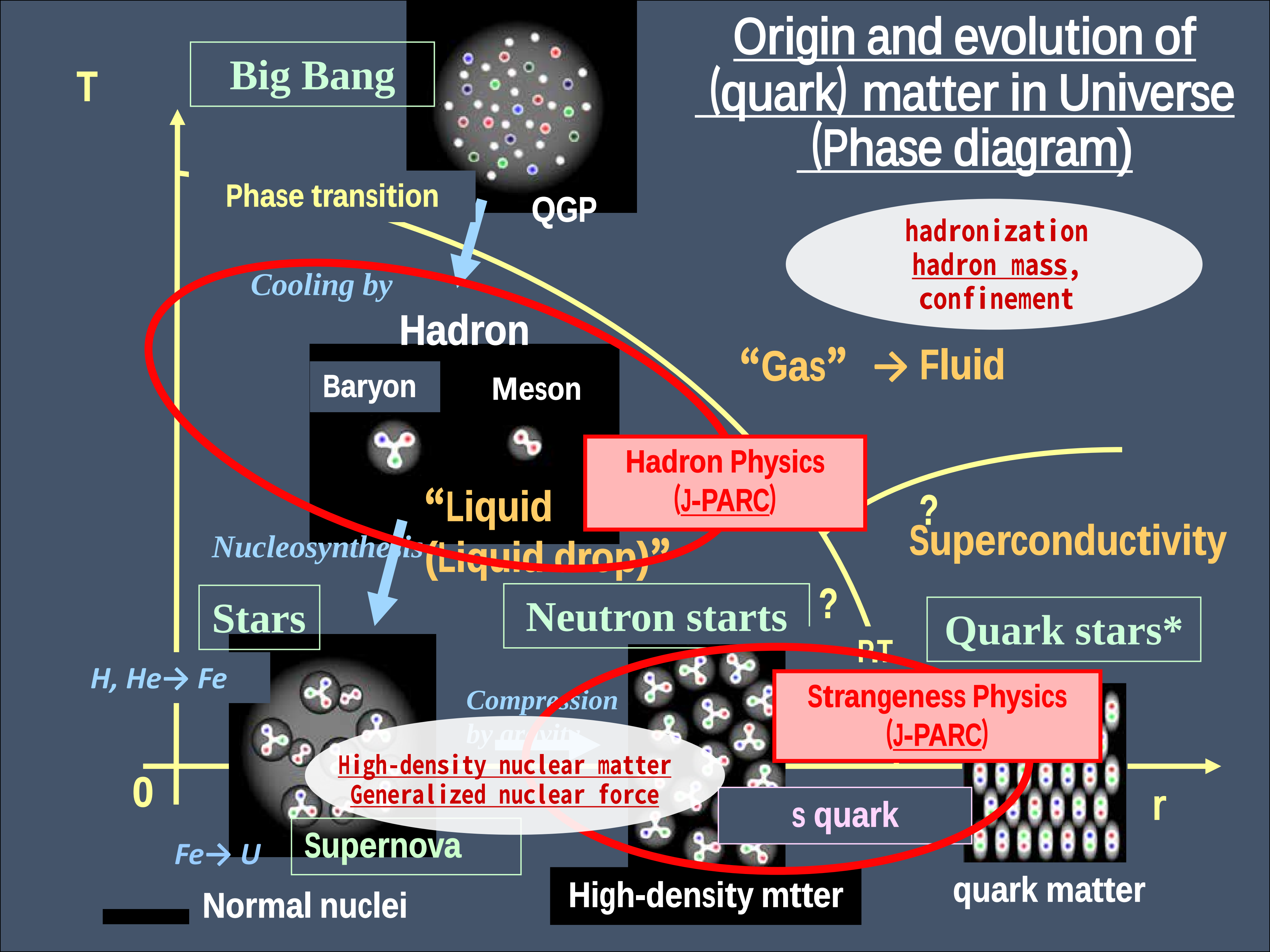
Hadron Experimental Facility (HEF)



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

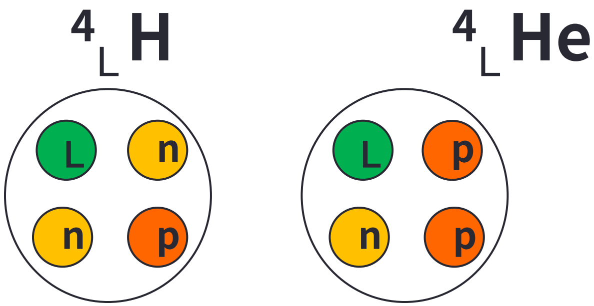
Contents



Origin and evolution of
(quark) matter in Universe
(Phase diagram)
T
Big Bang
QGP
Phase transition
Cooling by
Hadron
Baryon
Meson
"Liquid
(Liquid drop)"
hadronization
hadron mass,
confinement
"Gas" → Fluid
Hadron Physics
(J-PARC)
?
Superconductivity
Nucleosynthesis
Stars
Neutron starts
?
PT
Quark stars*
H, He→ Fe
Compression
by gravity
Strangeness Physics
(J-PARC)
High-density nuclear matter
Generalized nuclear force
0
s quark
r
Fe→ U
Supernova
Normal nuclei
High-density mtter
quark matter

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 ー Strangeness physics
    - n-rich L-nuclei (E10), multi-strangeness, K^{bar}N interaction (E15/E17/E27/E31)
  - Hadronization phase ー Hadron physics
    - exotic hadrons (E19) , charmed baryon spectroscopy (E50)

Blue: performed or on-go
Red: plan

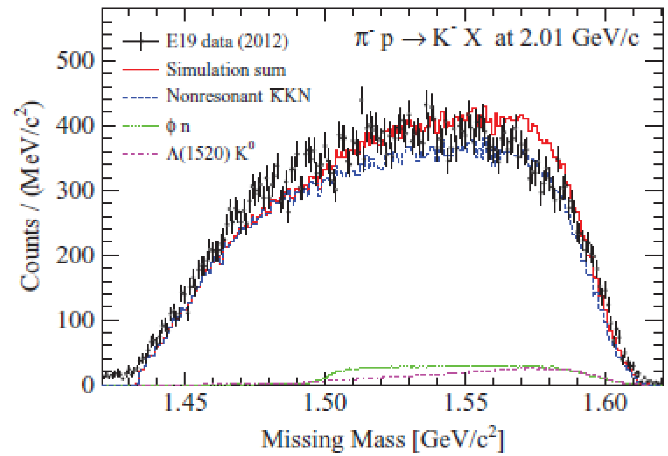
Results (1)

- E19:Search for Q^+ by p^-+p→K^-X

2010, Jan.2012

  - No peak was observed
  - U.L. of cross section : 0.28mb/sr
  - U.L. of Q^+ width: 0.36 (1.9) MeV for ½ $^+$ (½$^-$)

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



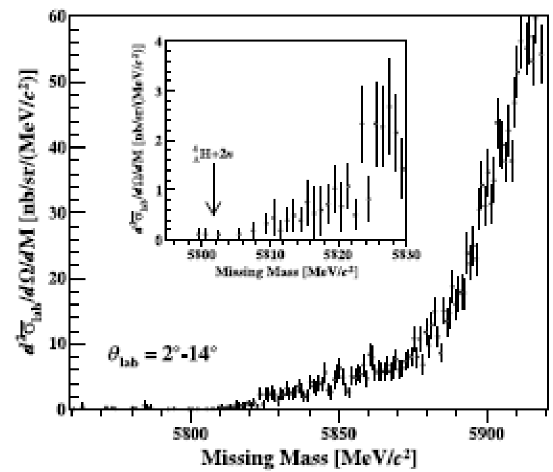
- E10:Neutron-rich $^6{}_L$H via the ^{6}Li(p^-,K^+)

Dec.2012-Jan.201

  - No peak was observed
  - U.L. of cross section :1.2nb/sr

⇔ Observation of 3 candidates
by FINUDA (PRL **108**,04251(2012))

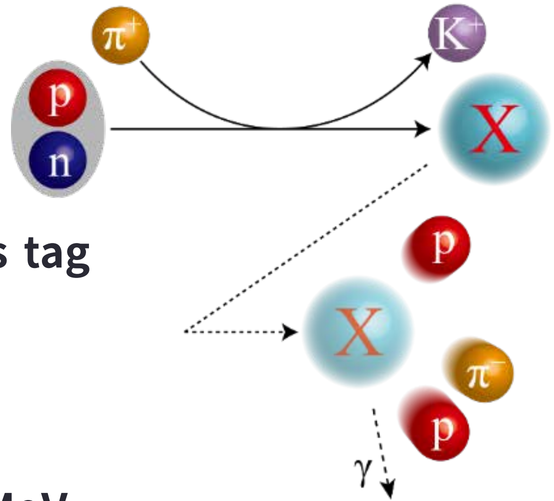
PLB 729, 39 (2014)



Results (2)

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

Experimental Method



Jun. 2012

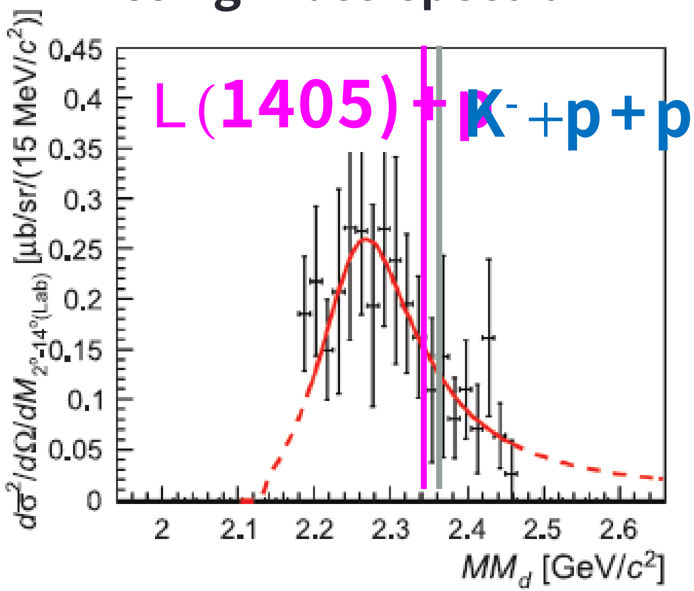
Missing mass spectrum is obtained with two protons tag

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	

Missing mass spectrum



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.

Analysis of inclusive spectrum was also published.

PTEP 2014, 101D03(2014)

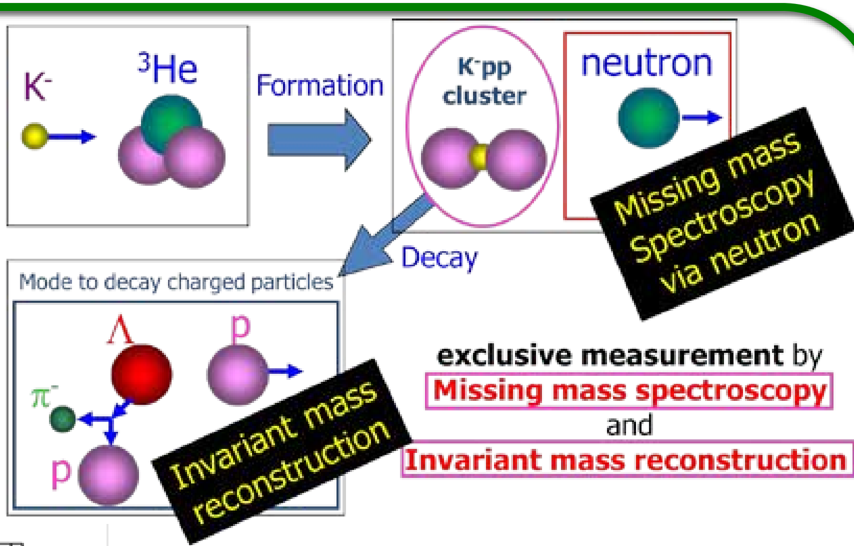
- **ΣN-ΛN cusp**
- **Shift of Y* bump**

Results (3)

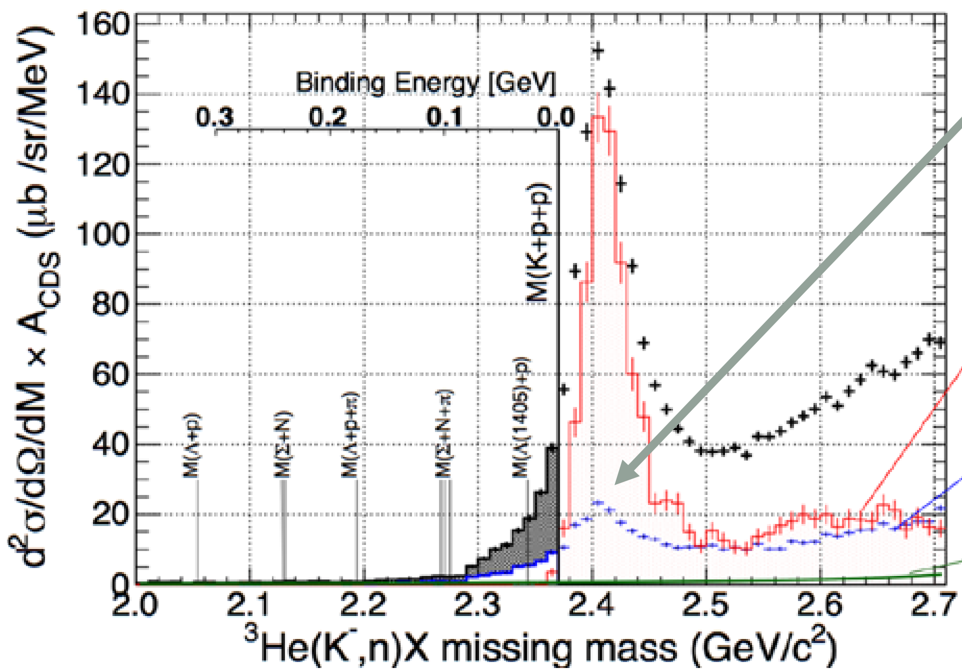
- **E15: Search for K^-pp bound states by the $^3He(K^-,n)X \rightarrow \Lambda p$**

1^{st}- stage RUN with 1% of the proposal

arXiv:1408.5637 [nucl-ex]May 2013



exclusive measurement by
Missing mass spectroscopy
and
Invariant mass reconstruction



Significant enhancements were observed in a bound-region

"semi"-inclusive
~10MeV/c² resolution

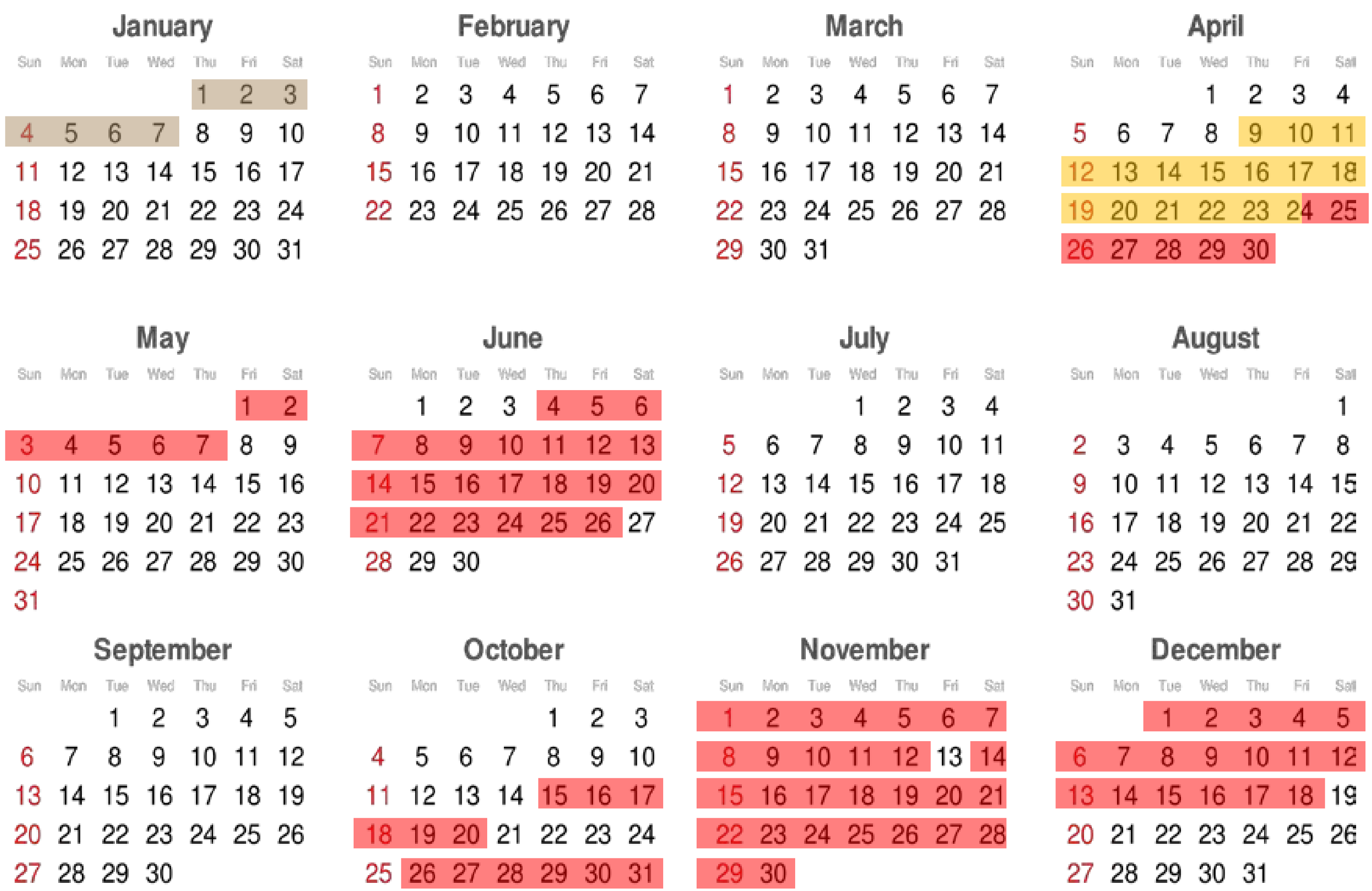
K^0_s-tagged x 8

Contribution of $\Sigma \rightarrow np$
(No other contribution in a bound-region due to kinematical limitations)

Accidental

Hadron Beam Operation in 2015

2015 Renovation Test operation User operation



Restart of Hadron Beam Operation

Jan. 6 7 8

Renovation

Apr. 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27

Test operation

The first beam extraction to the Hadron hall (3kW)

The first beam injection to the target

12kW test operation started.

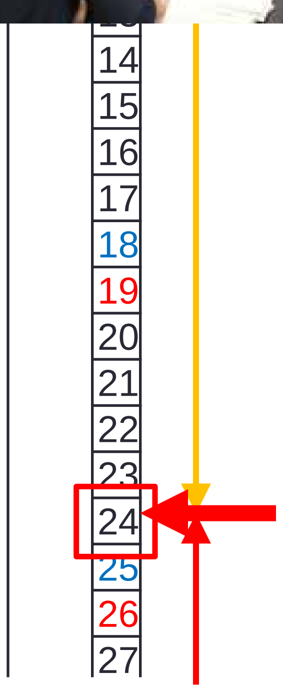
Facility inspection for the license as a radiation facility

24kW test operation started.

The certificate was issued.

- The whole system, including newly installed equipment, was checked during the test operation period.
- In each step of the beam power improvements, new target system, monitoring system, etc. were confirmed to work properly.

Restart of Hadron Beam Operation



User operation restarted with the proton beam power of 24kW!

(Almost 2 years after the accident)

朝日新聞　２０１５年４月２５日　朝刊　２８ページ　茨城全県

J－PARC

実験施設が再開

放射能漏れから2年

東海村にある加速器実験施設「J－PARC」で24日、放射性物質の漏出事故＝メモ＝を起こしたハドロン実験施設の運転が約2年ぶりに再開された。

「標的温度、異常なし」

午前11時すぎ、陽子ビームを標的に当てる作業を開始。運転管理室では職員が標的の温度や放射能濃度のモニター画面を確認した。

この日から、国内外の大学や研究機関の三つの実験が始まった。他に約10の実験が控えているという。

放射性物質の漏出事故

2013年5月、陽子ビームを標的の金に当てて粒子を発生させる実験中に起きた。機器劣化による誤作動で設定値を大きく超えるビームが当たり、金の中の放射性物質が蒸発。研究者ら34人が被曝（ひばく）し、排気ファンを回したことで放射性物質が屋外に漏れた。警報が出た後も4時間以上実験を続け、自治体への報告が1日半遅れたことが批判を浴びた。

事故は国際原子力事象評価尺度で、1995年の高速増殖炉もんじゅ（福井県）のナトリウム漏れ事故と同じ「レベル1」とされた。

運転管理室で標的の温度などを確認する職員ら＝東海村のJ－PARC

J－PARCは、日本原子力研究開発機構と高エネルギー加速器研究機構が共同で運営。ハドロン実験施設は2009年に完成した。陽子ビームの出力が高く、世界最高性能の施設とされる。標的となる金などの原子核と衝突させて粒子を作り出し、物質の起源や宇宙の成り立ちを探究している。事故前の12年度は利用期間中、常時約100人が利用した。

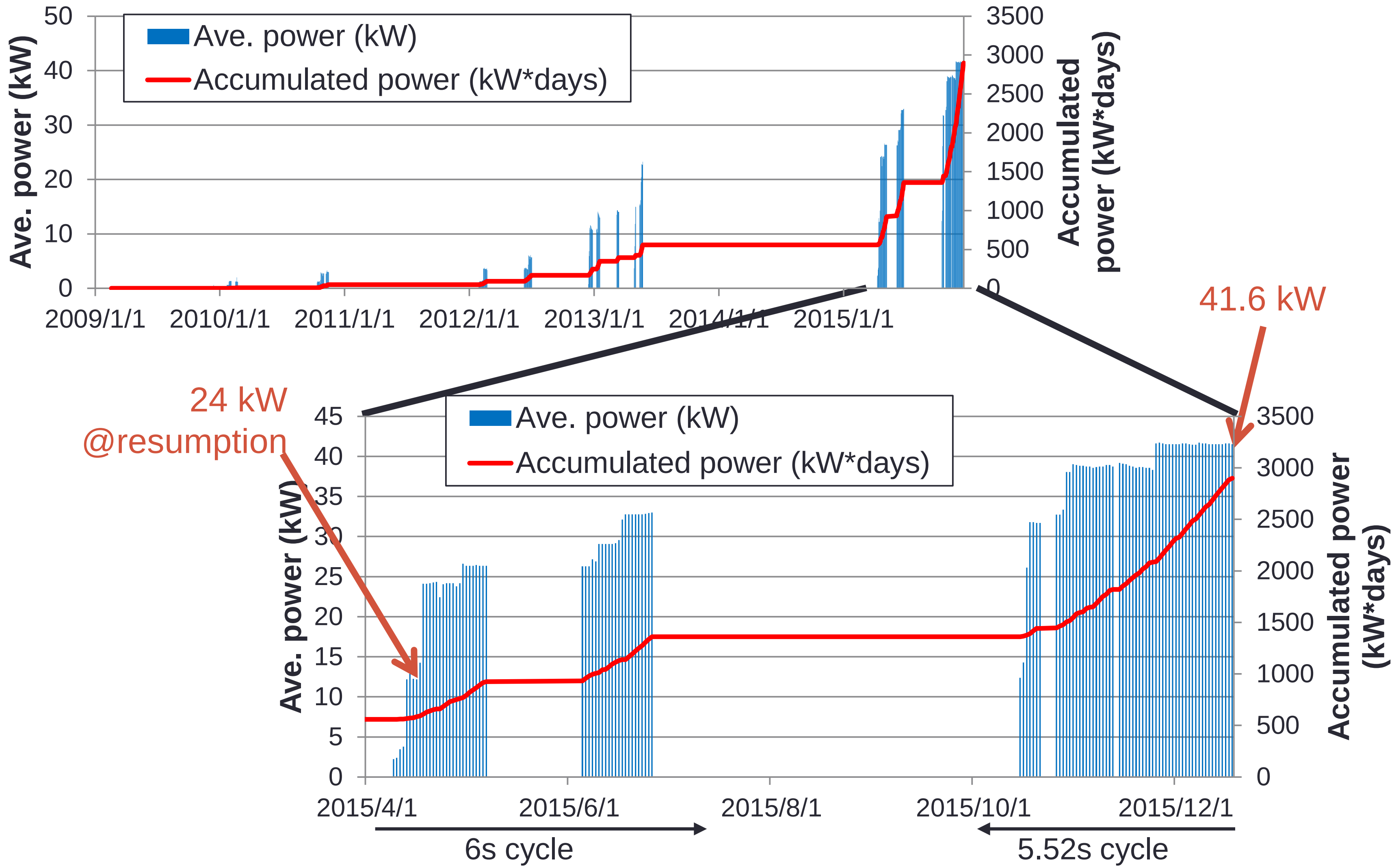
事故で八つの実験が中断や延期を余儀なくされた。事故当時、チームの責任者として実験に取り組んでいた大阪大の山中卓教授（高エネルギー物理学）は「2年は長かったが、安全対策や住民への説明を丁寧にした結果、ようやく研究を進められるのでホッとしている」と話す。

J－PARC側は、約19億円をかけて安全対策を講じた。異常な量のビームが出る原因となった電源装置に劣化対策を施し、放射性物質が外に漏れないよう排気ファンを撤去。異常時の行動基準もマニュアルに盛り込んだ。こうした再発防止策を踏まえ、県や村は先月、運転再開を了承した。

事故以降、一市民の立場でJ－PARCの動向をブログで発信してきた常総市の行政書士古性隆さん(50)は、ウェブサイトでの会議資料の掲載など情報公開が進んだことに一定の評価をしつつ、釘を刺す。「研究者と住民との安全認識の差はだいぶ縮まった。ただ、施設全体の災害対策でまだ不安な点がある。今後も住民目線で監視したい」

J－PARCの斉藤直人センター長は「安全確保を最優先に施設を運営する。最先端の研究成果を生み出し、社会に貢献していきたい」と話している。（箱本友紀子）

Development of Beam Intensity



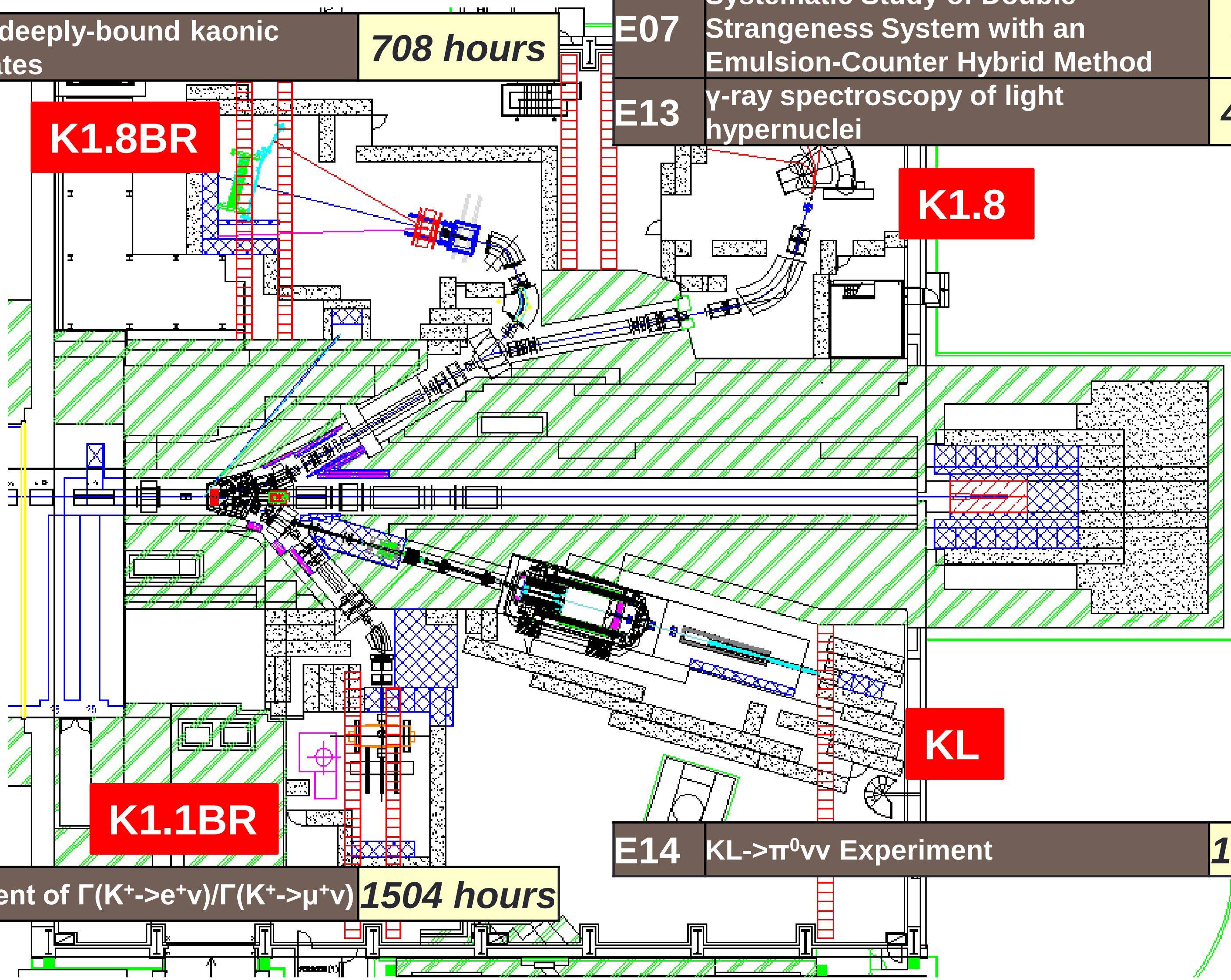
Accumulated beam time and intensity for HD

Before accident (Feb, 2009 – May, 2013): 1.26x10^6 spills※, 560 kW*days

After accident (Apr, 2015 – Dec, 2015): 1.05x10^6 spills, 2338 kW*days

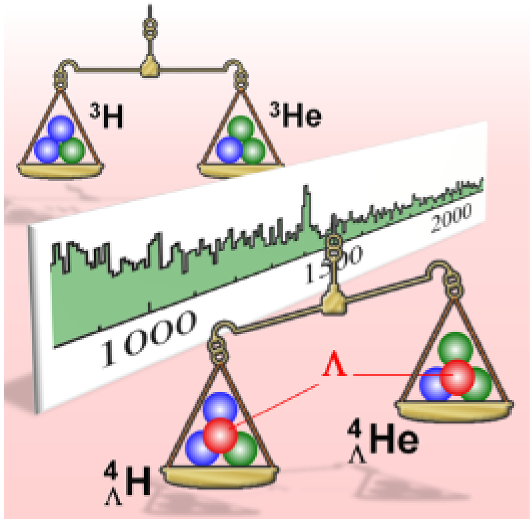
※spill: # of beam shots to HD

Beam time used by experiments in 2015



E05	Spectroscopic Study of Ξ- Hypernucleus	*319 hours*
E07	Systematic Study of Double Strangeness System with an Emulsion-Counter Hybrid Method	*42 hours*
E13	γ-ray spectroscopy of light hypernuclei	*435 hours*
E15	search for deeply-bound kaonic nuclear states	*708 hours*
E14	$K_L \to \pi^0 \nu\nu$ Experiment	*1509 hours*
E36	Measurement of $\Gamma(K^+ \to e^+\nu)/\Gamma(K^+ \to \mu^+\nu)$	*1504 hours*

PHYSICAL REVIEW LETTERS
moving physics forward



EDITORS' SUGGESTION

Observation of Spin-Dependent Charge Symmetry Breaking in ΛN Interaction: Gamma-Ray Spectroscopy of $^{4}_{\Lambda}\mathrm{He}$

The energy spacing of the spin-doublet states in the $^{4}_{\Lambda}$He hypernucleus indicate a large spin dependent charge symmetry breaking in the ΛN interaction.

T. O. Yamamoto *et al.* (J-PARC E13 Collaboration)

Phys. Rev. Lett. **115**, 222501 (2015)

Press-released from Tohoku U., KEK, JAEA, J-PARC

Production Target

50 kW target

- April, 2015 -
- Indirect cooling
- Currently working

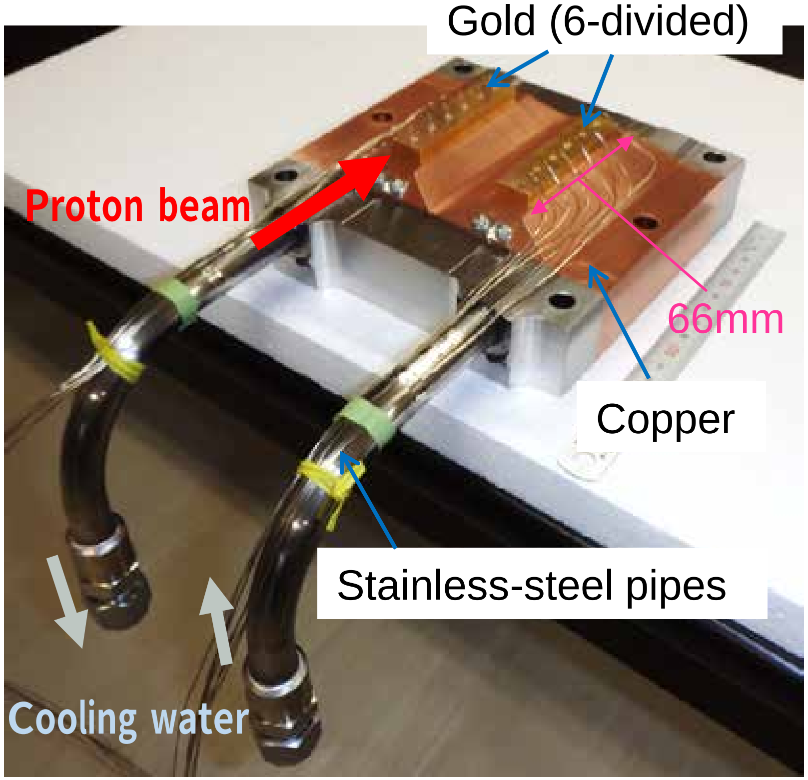
80 kW target

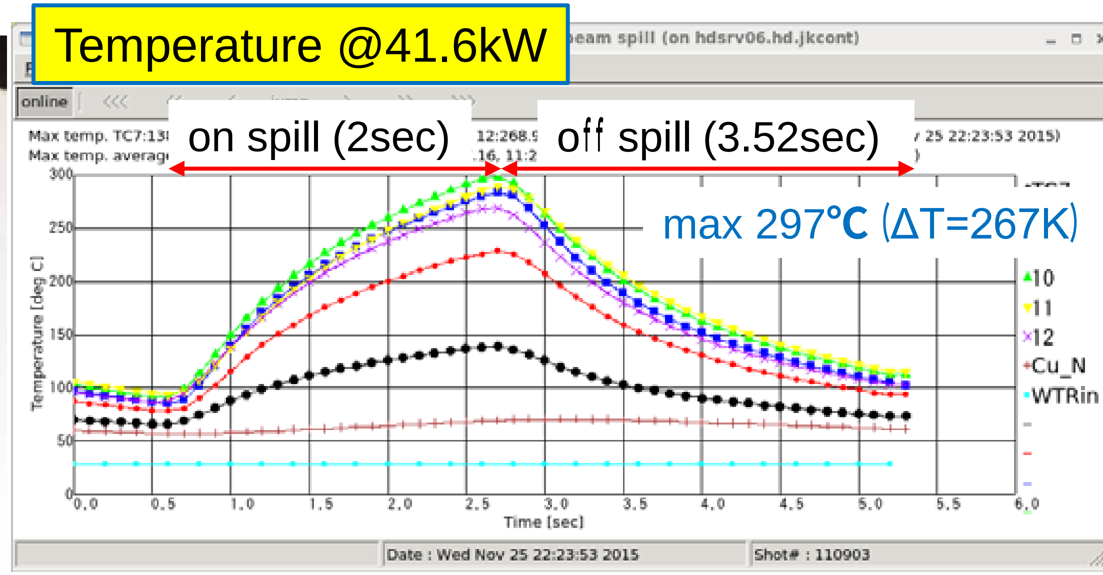
- Fall, 2017 or 2018 -
- Indirect cooling
- Ready to manufacture

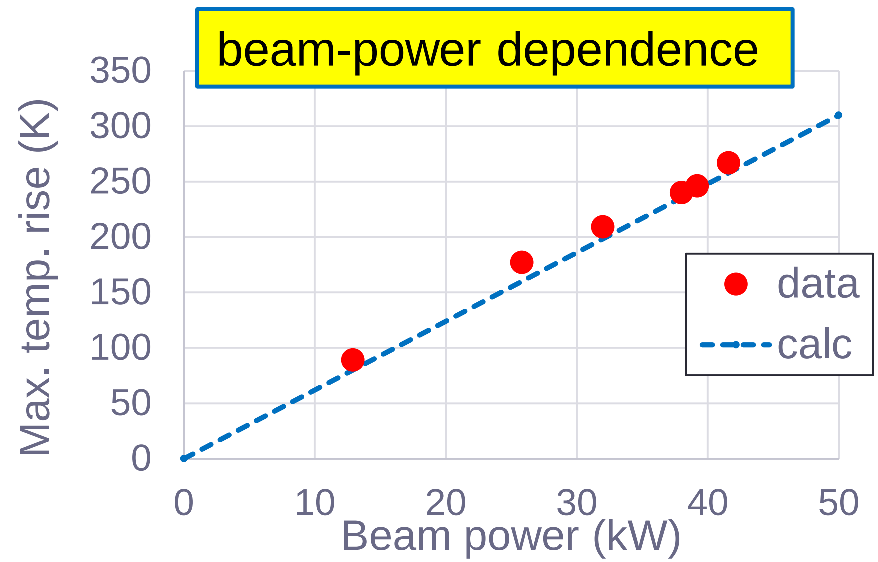
>100 kW target

- Around 2020/2021 -
- Direct cooling
- Under R&D

Current Production Target

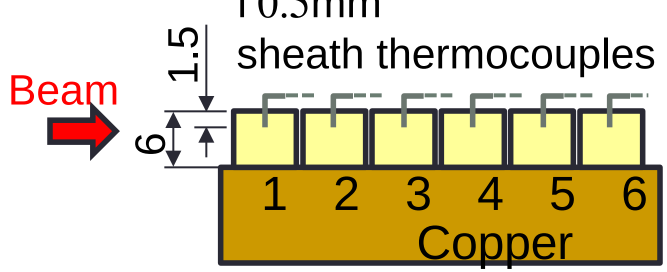






Measured temperature was in good agreement with calculation

Temperature of each gold piece was measured with thermocouples every 100ms



Production Target

50 kW target

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80 kW target

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- Ready to manufacture

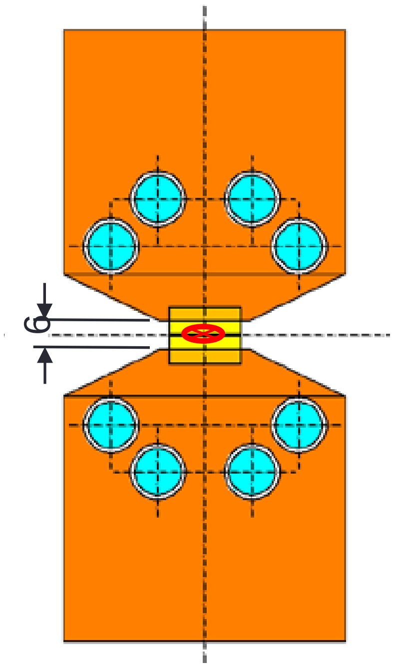
>100 kW target

- Around 2020/2021 -
- Direct cooling
- Under R&D

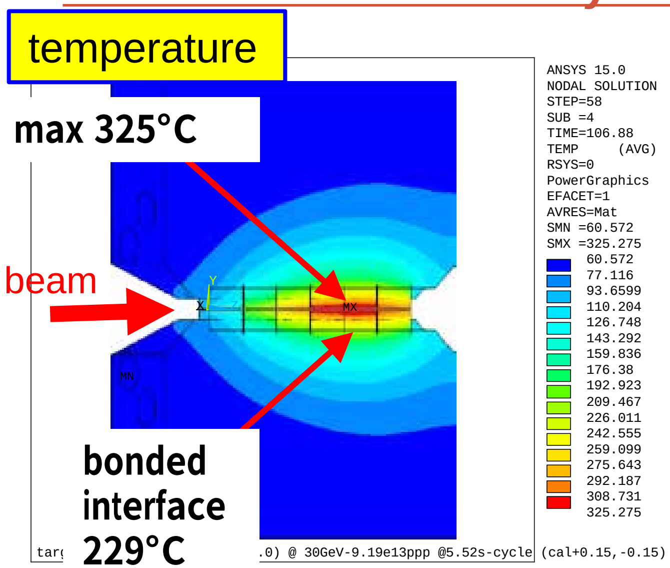
Next Indirect Cooling Target

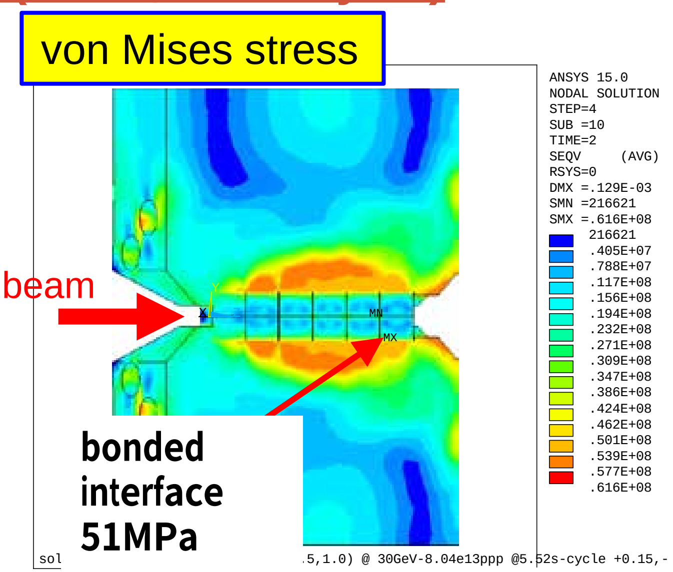
- Gold target on Cu holder
- Indirect water cooling as the current target
- Relatively straightforward to develop.
- ~80 kW proton beam can be accepted.
- Will be installed as a replacement of the current target.

View from upstream



Result of Thermal Analysis (80kW, 5.52s cycle)





vertical expansion: max 0.10mm

Bonding strength:
128MPa(@229°C)

Design margin: 2.5

Ready to manufacture

Production Target

50 kW target

- April, 2015 -
- Indirect cooling
- Currently working

80 kW target

- Fall, 2017 or 2018 -
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>100 kW target

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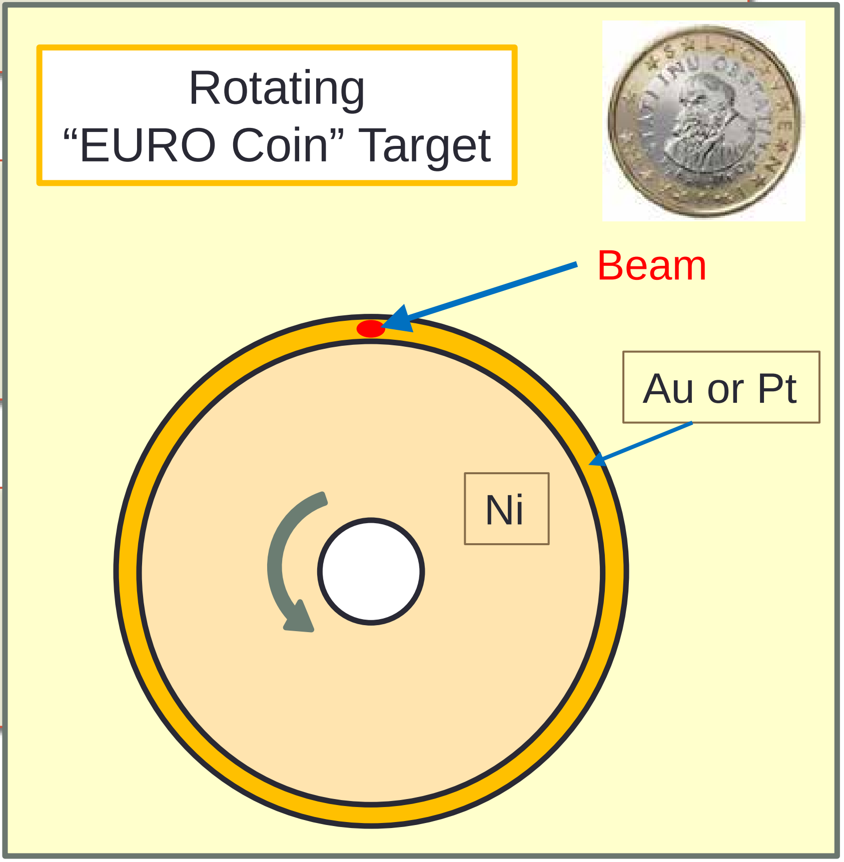
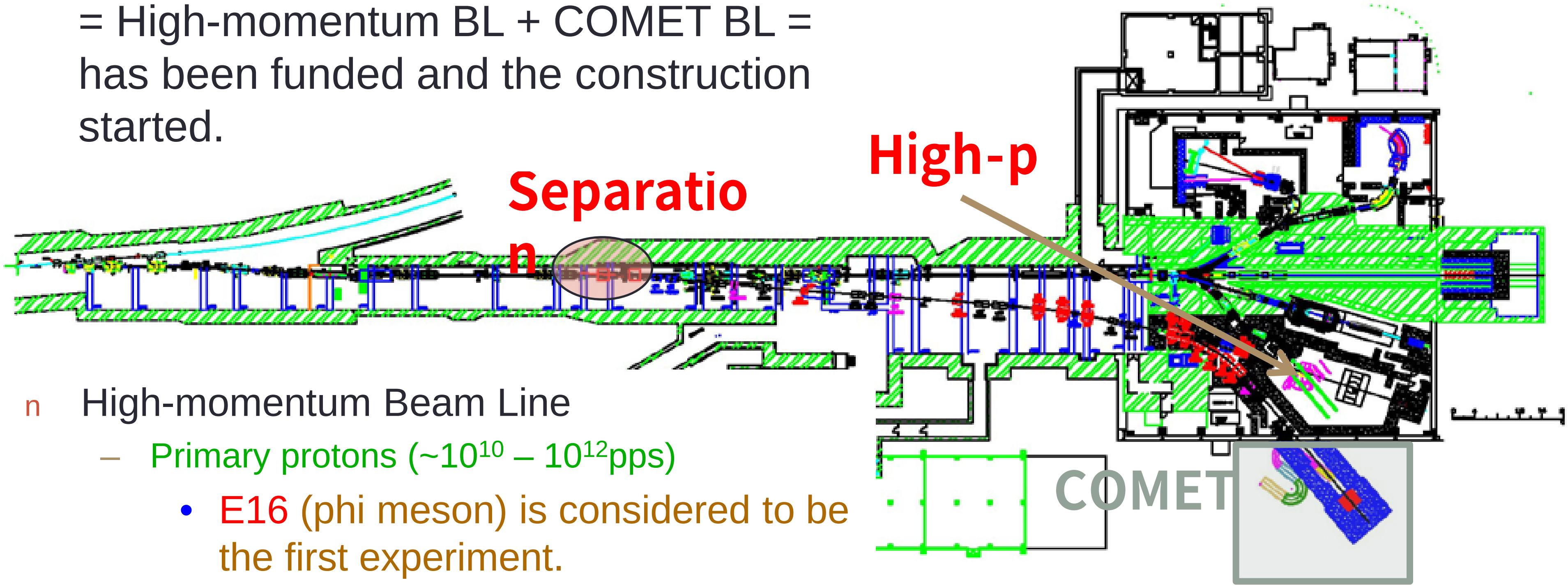


Contents

New Primary Proton Beam Line

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

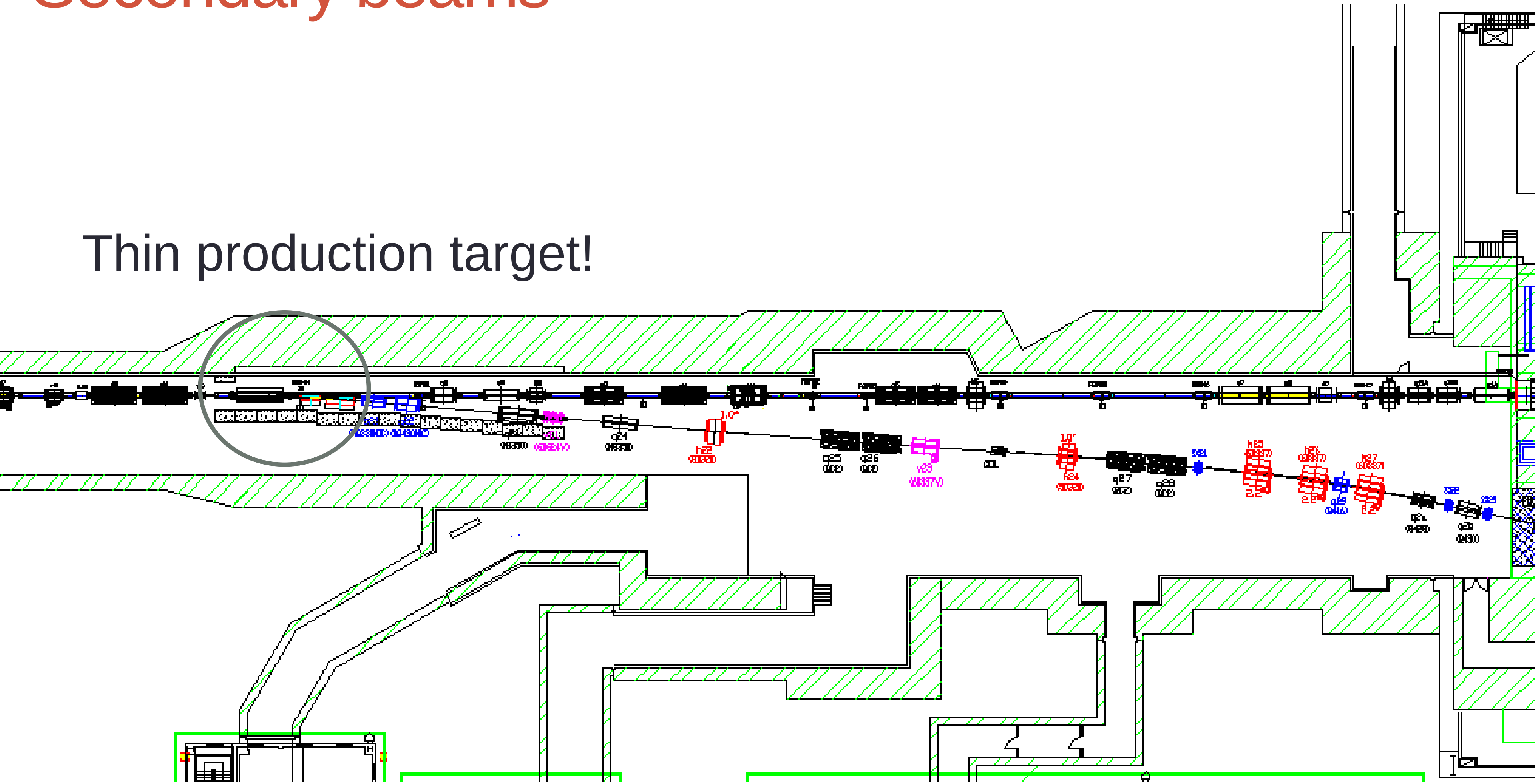


- High-momentum Beam Line
  - Primary protons (~10^{10} – 10^{12}pps)
    - E16 (phi meson) is considered to be the first experiment.
  - Unseparated secondary particles (pi, …)
    - High-resolution secondary beam by adding several quadrupole and sextupole magnets.

- 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.

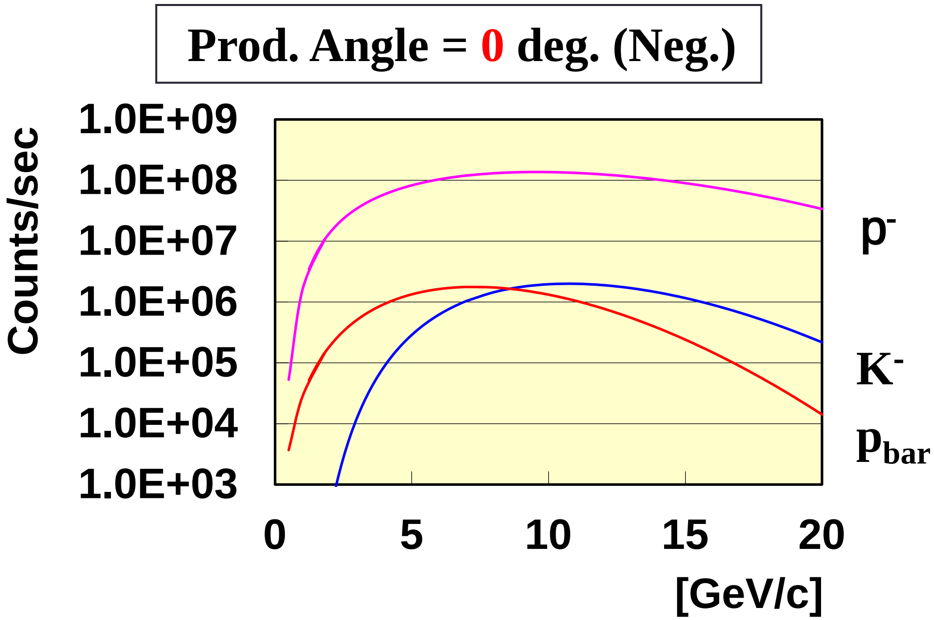
Secondary beams

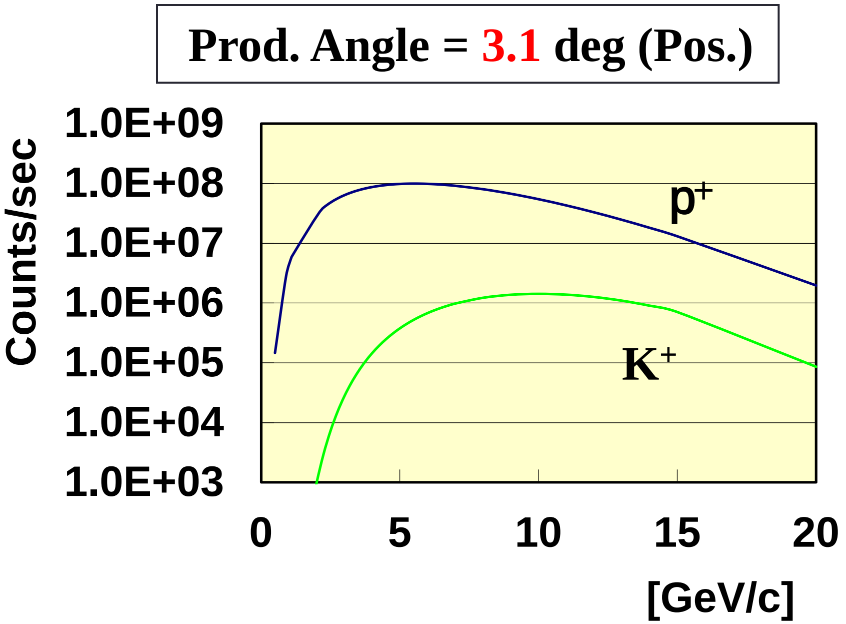
Thin production target!



Unseparated Secondary Beam

Noumi



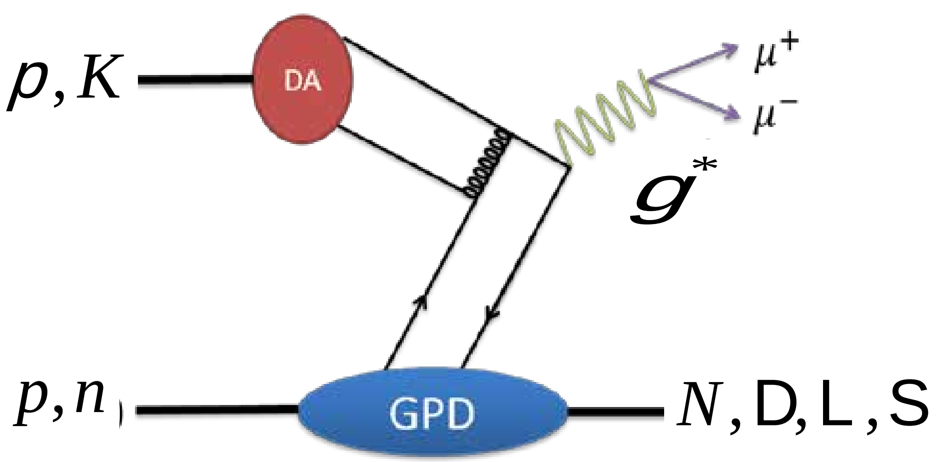


* Sanford-Wang:15 kW Loss on Pt, Acceptance :1.5 msr%, 133.2 m

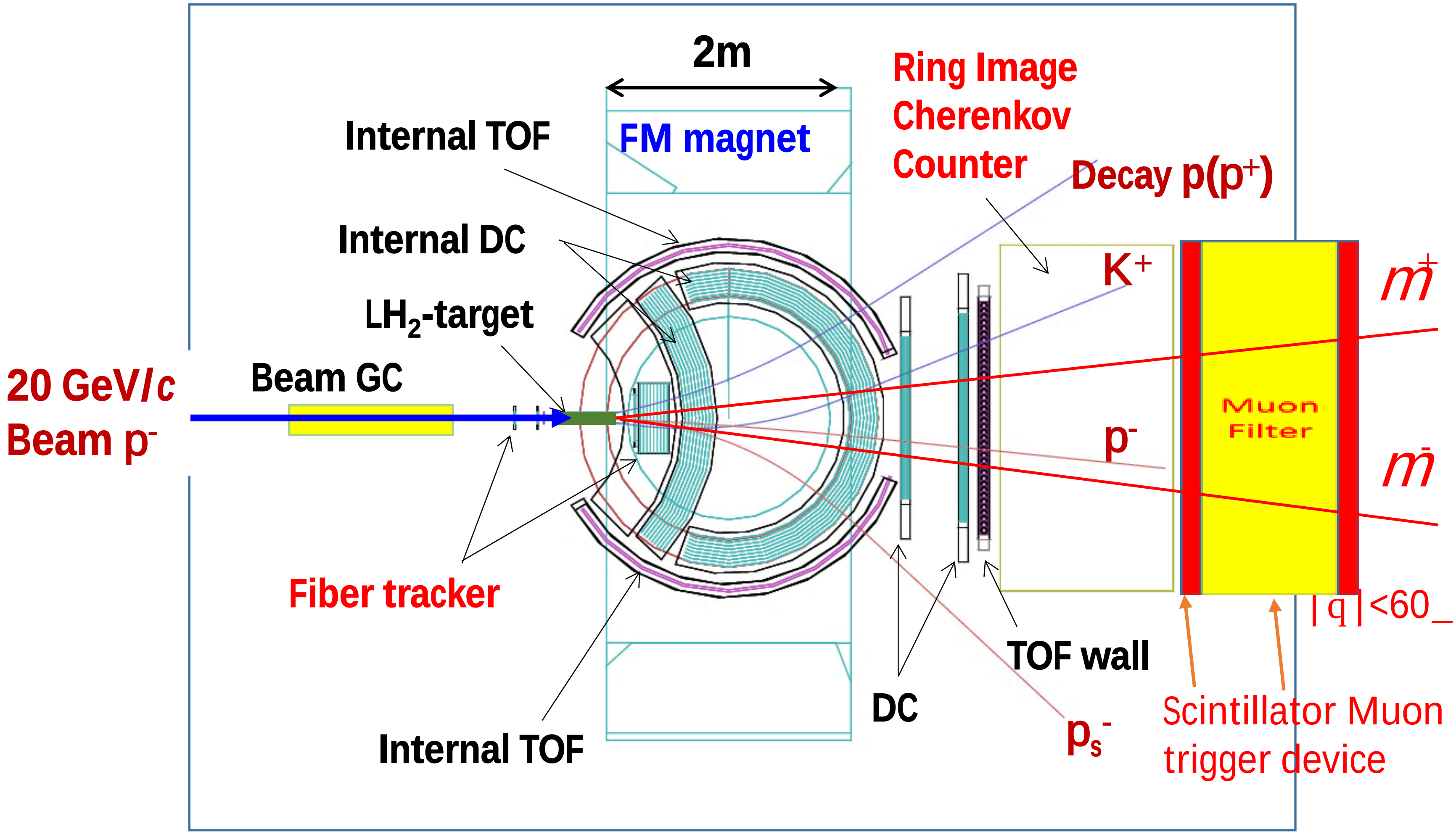
“GPD” and “Transition GPD”

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

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



J-PARC E50 Spectrometer + MuID



Acceptance: ~ 60% for *D, ~80% for decay p+**
Resolution: *Dp/p*~0.2% at ~5 GeV/*c* (Rigidity: ~2.1 Tm)

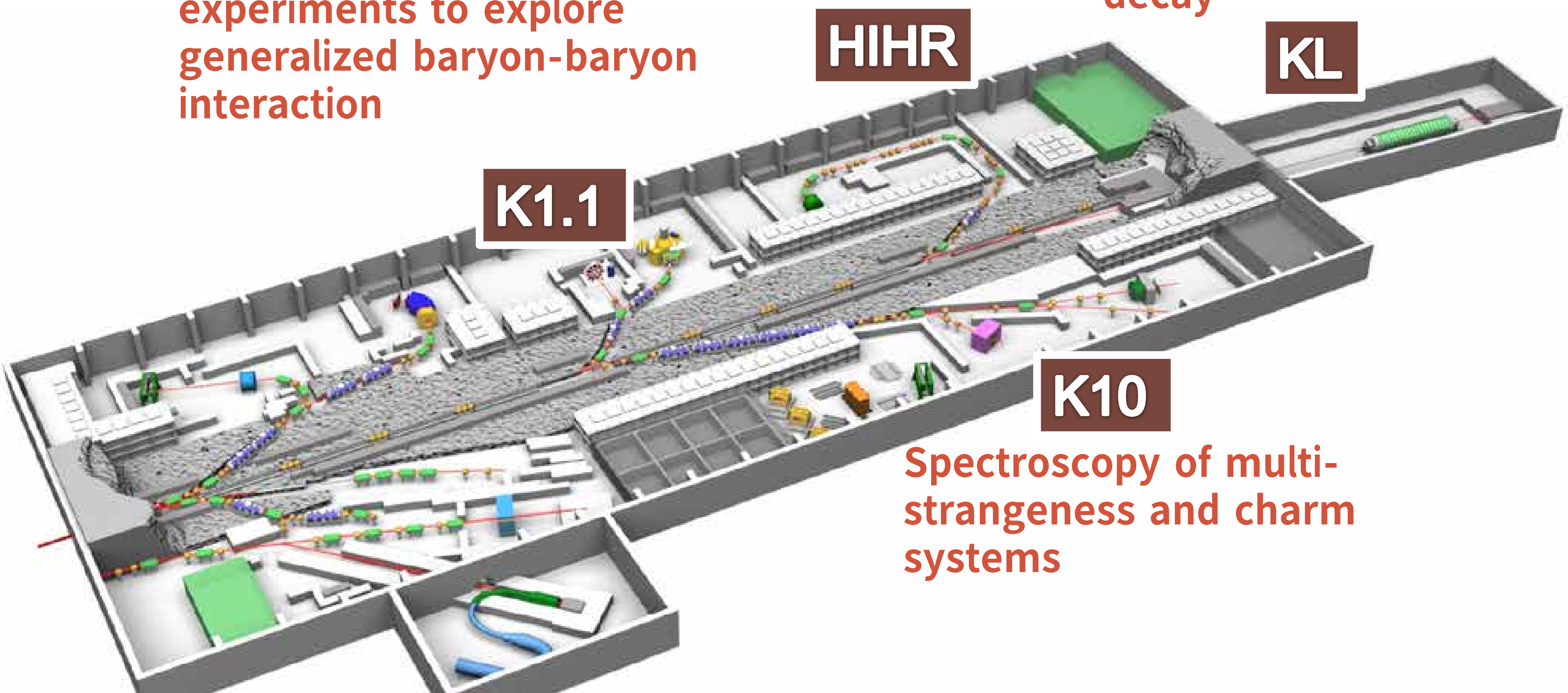
Contents

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.
- A review committee at MEXT selected the J-PARC future project including the Hadron Hall extension as one of the 11 major projects on its roadmap.
- 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

- The beam operation at the Hadron Facility restarted from April, 2015.
- The beam power at the restart was 24kW, and then improved gradually to 42kW in December.
- The high-momentum beam line is under construction, and will be available in a few years.
- The extension of the Hadron Hall has been proposed, and got a good message from initial reviews.