

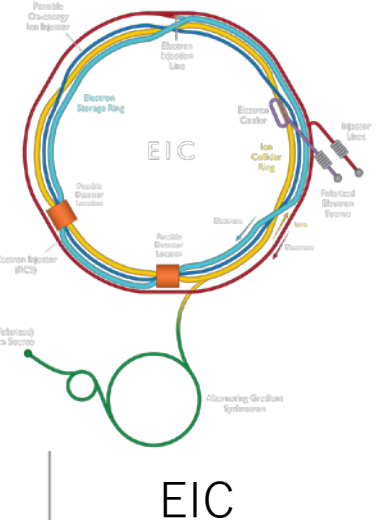
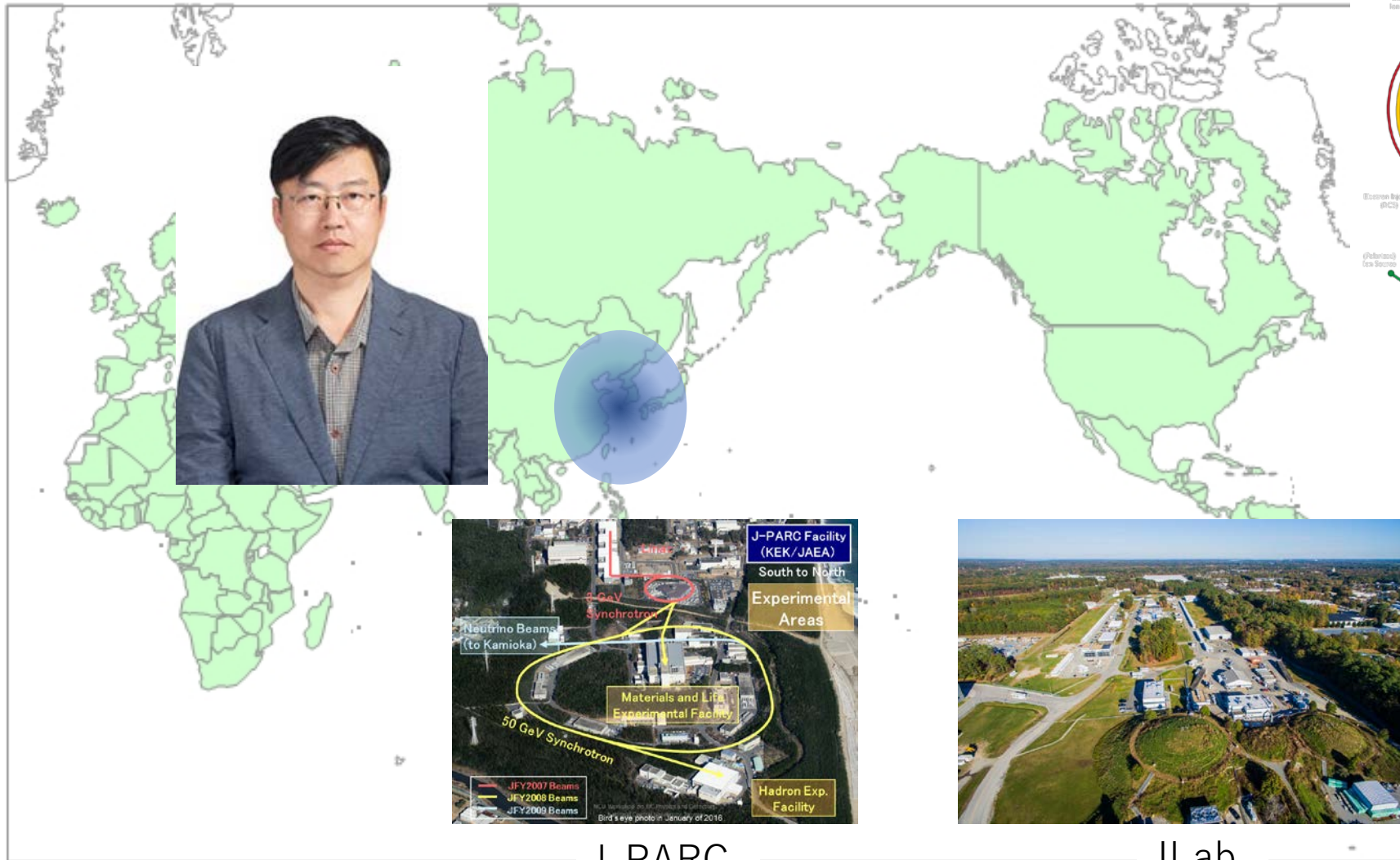
# Hadronic Physics at J-PARC with the memory of Prof. Oh

July 12, 2023

Shinya SAWADA

KEK/J-PARC

# Prof. Oh has been a center of the collaboration on hadronic physics in Asia and worldwide...



# J-PARC

Japan Proton Accelerator Research Complex

**J-PARC Facility  
(KEK/JAEA)**

South to North

**Experimental  
Areas**

Linac

3 GeV  
Synchrotron

Neutrino Beams  
(to Kamioka)

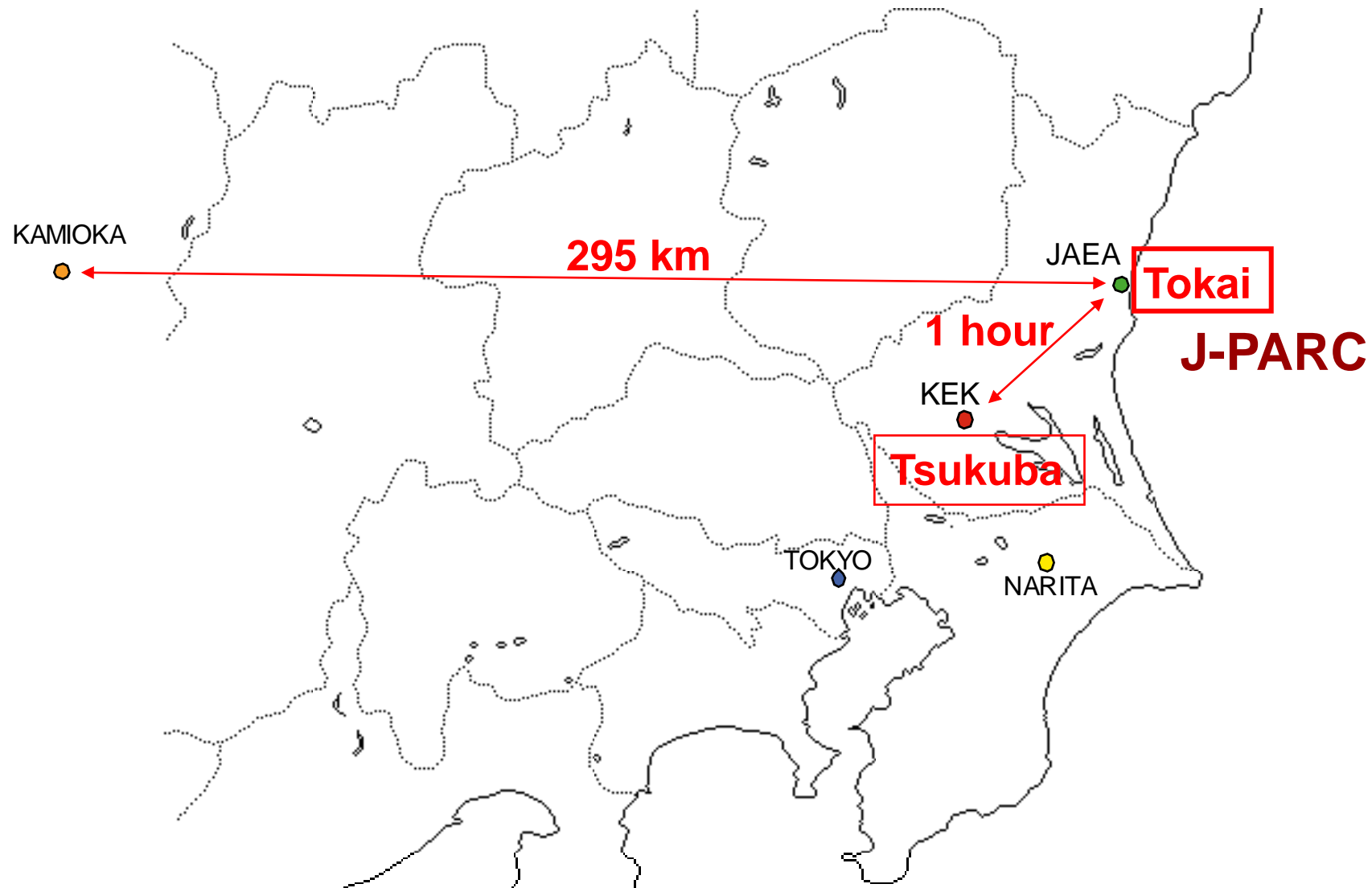
**Materials and Life  
Experimental Facility**

50 GeV Synchrotron

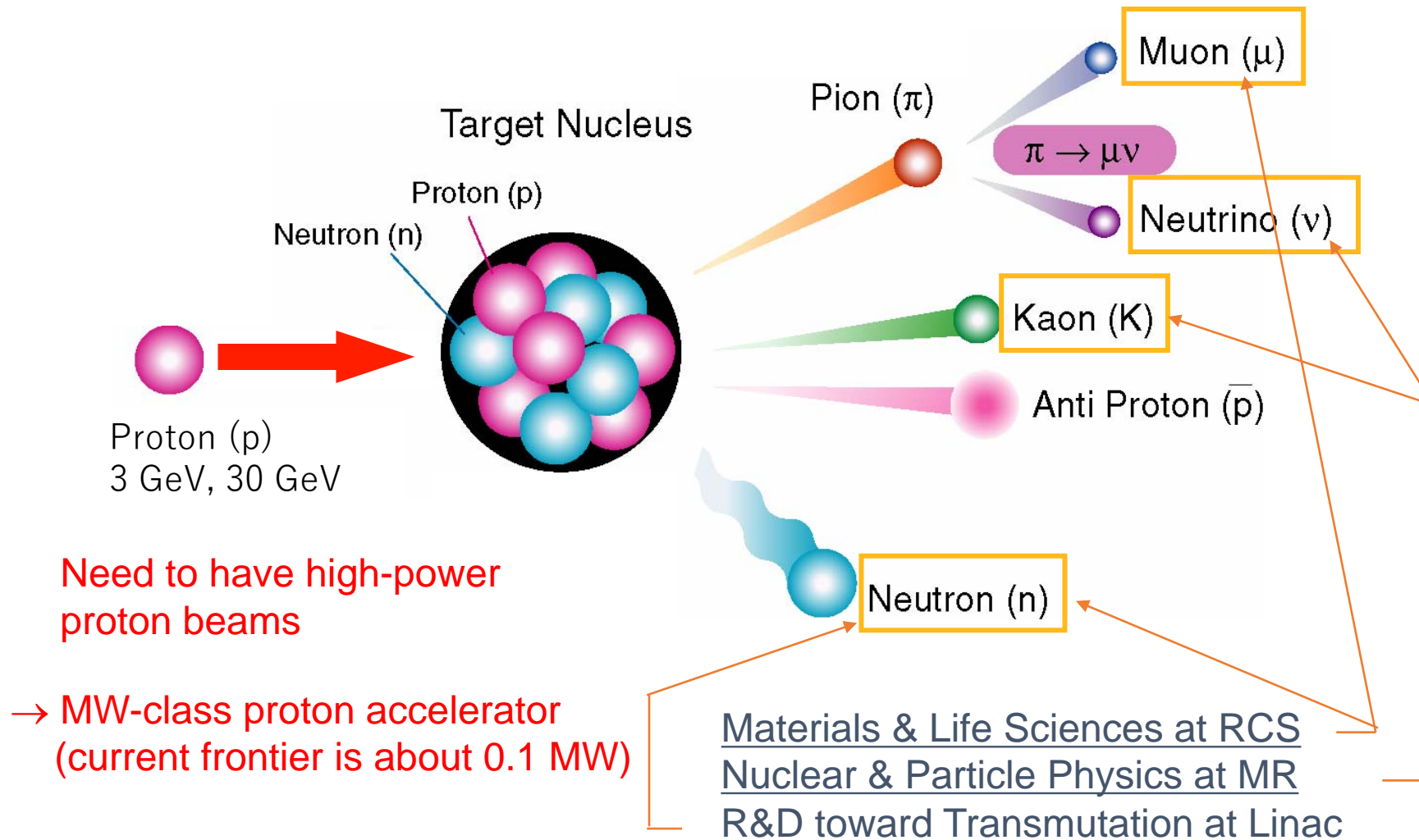
**Hadron Exp.  
Facility**

- JFY2007 Beams
- JFY2008 Beams
- JFY2009 Beams

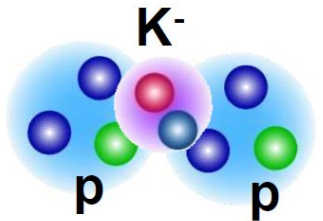
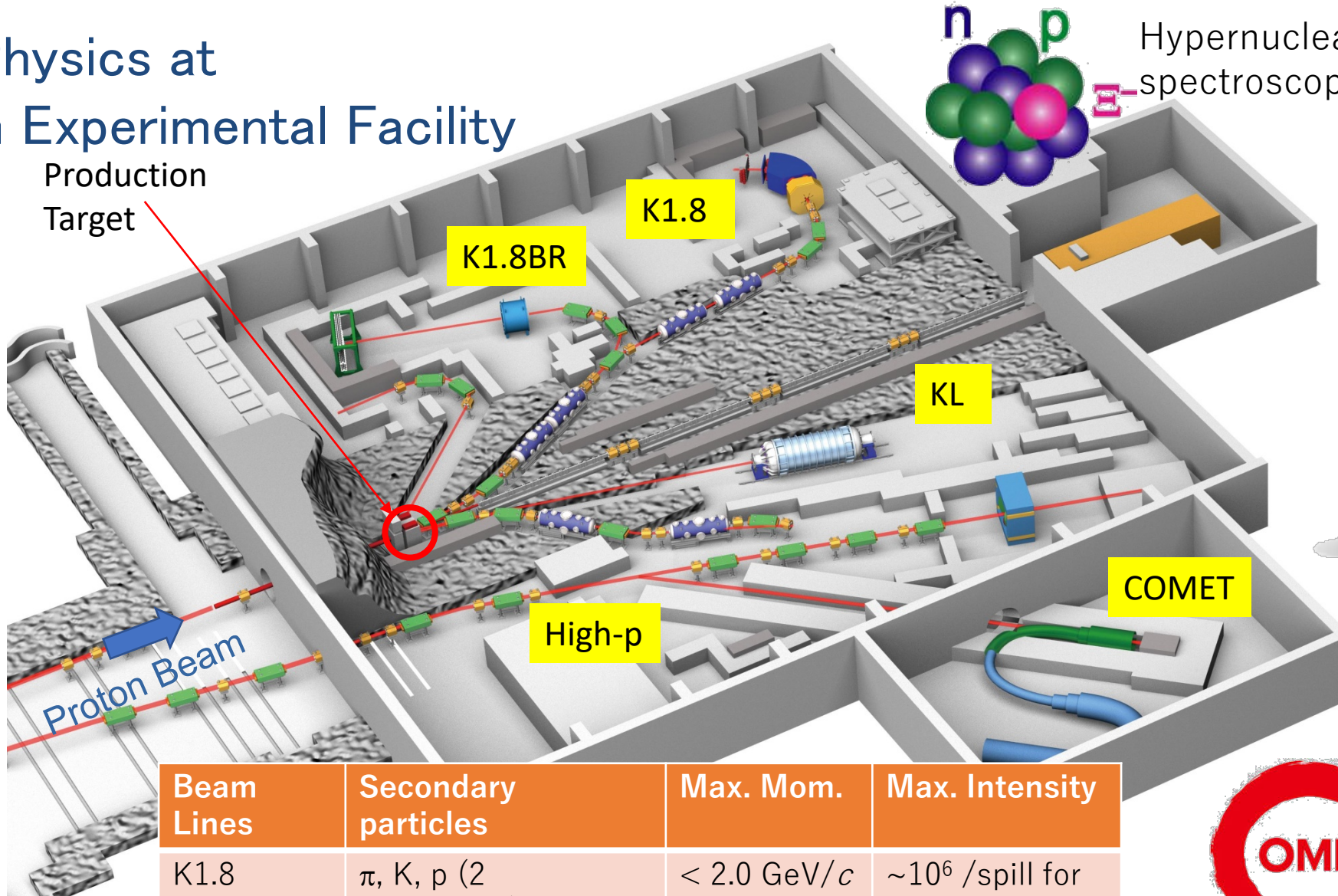
# Location of J-PARC



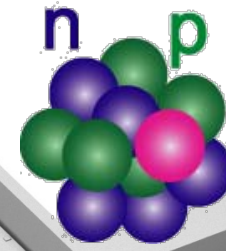
# Goals of J-PARC



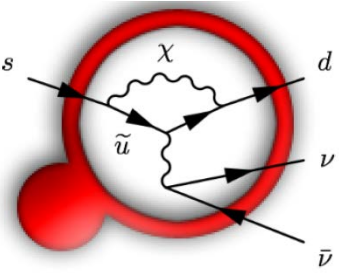
# Hadronic Physics at the Hadron Experimental Facility



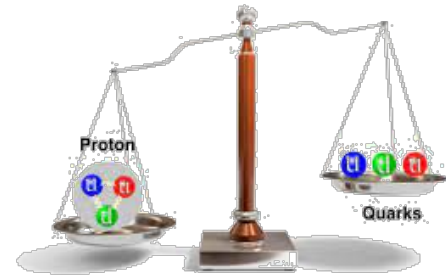
Kaon in nuclei



Hypernuclear spectroscopy



Neutral kaon rare decay



QCD mass and chiral symmetry

Beam Lines	Secondary particles	Max. Mom.	Max. Intensity
K1.8	$\pi$ , K, $p$ (2 separators)	$< 2.0 \text{ GeV}/c$	$\sim 10^6$ /spill for $K^-$
K1.8BR	$\pi$ , K, $p$ (1 separator)	$< 1.1 \text{ GeV}/c$	$\sim 10^5$ /spill for $K^-$
KL	Neutral Kaon	$\sim 2.1 \text{ GeV}/c$	$\sim 10^7$ /spill



Electron-muon conversion

Recent

# Achievements in research at the Hadron Experimental Facility

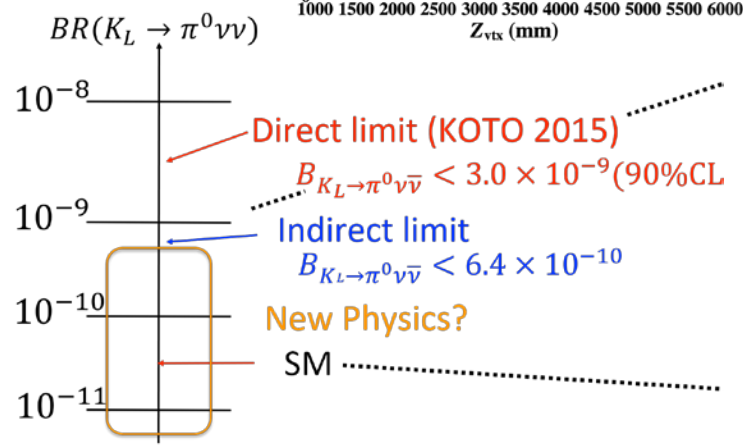
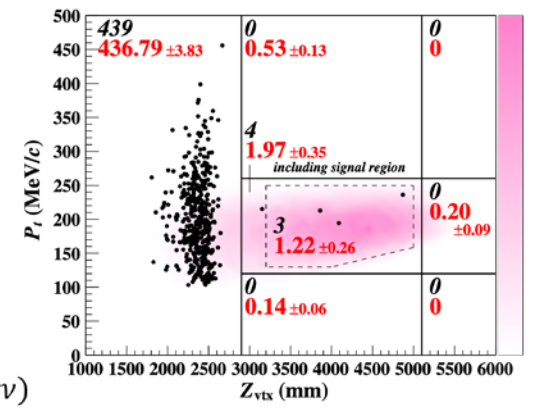
## Flavor Physics

$K_L^0 \rightarrow \pi^0 \nu \bar{\nu}$  search @ KOTO

→ Approaching the SM sensitivity for CP violation

KOTO 2016-18

KOTO 2015  
Single Event Sensitivity =  $3 \times 10^{-9}$

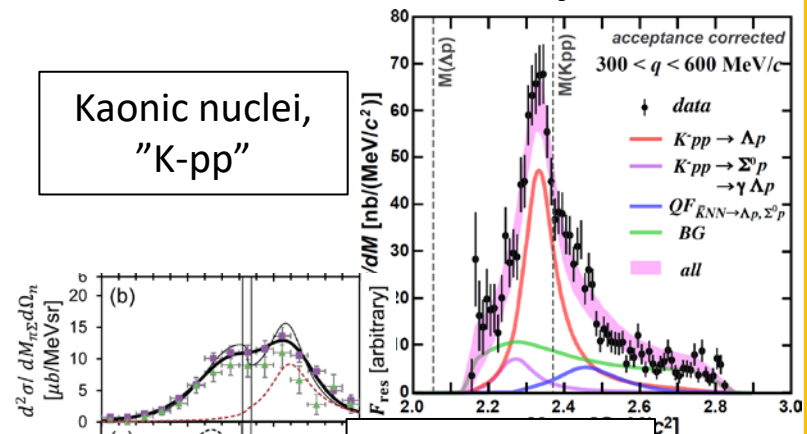


## Hadron Physics

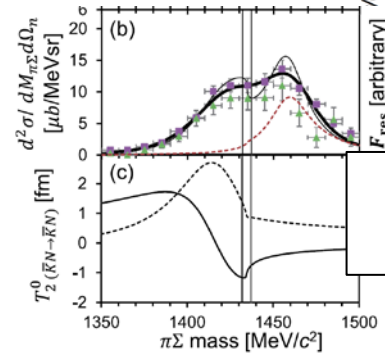
Observation of an exotic hadron bound system including  $K^-$  meson

→ Established a new direction to understand meson-baryon int.

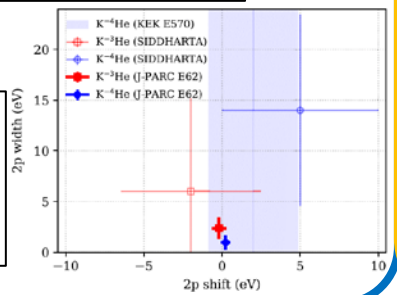
Kaonic nuclei, "K-pp"



Pole position of  $\Lambda(1405)$



Ultra-precise measurement of kaonic atoms

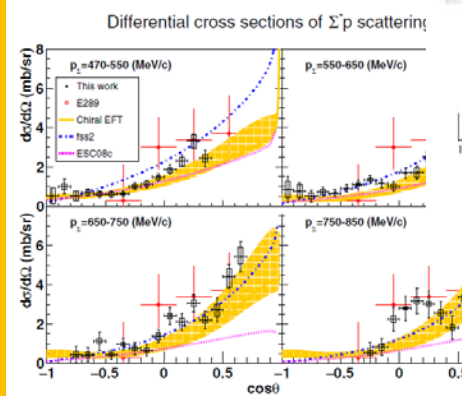
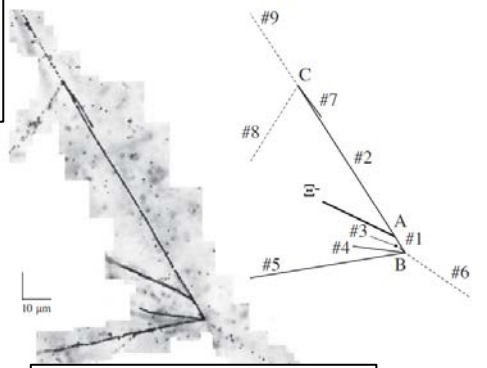


## Strangeness Nuclear Physics

A lot of progress in hypernuclear research

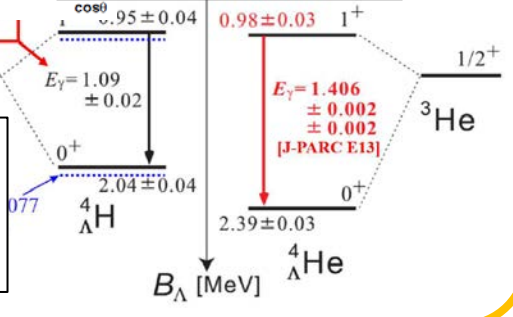
→ Clarified attractive  $S=-2$   $\Xi N$  interaction and deepened  $S=-1$   $\Lambda N, \Sigma N$  interactions

Observation of  $\Xi$  hypernuclei



First precise hyperon-nucleon scattering

Charge-symmetry breaking in the  $\Lambda N$  interaction



## Effective interactions of hyperons and mass-radius relation of neutron stars


Yeunhwan Lim,<sup>1,\*</sup> Chang-Hwan Lee,<sup>2,†</sup> and Yongseok Oh<sup>3,4,‡</sup>

<sup>1</sup>*Cyclotron Institute and Department of Physics and Astronomy, Texas A&M University, College Station, Texas 77843, USA*

<sup>2</sup>*Department of Physics, Pusan National University, Busan 46241, Korea*

<sup>3</sup>*Department of Physics, Kyungpook National University, Daegu 41566, Korea*

<sup>4</sup>*Asia Pacific Center for Theoretical Physics, Pohang, Gyeongbuk 37673, Korea*

 (Received 9 August 2017; published 18 January 2018)

We examine the role of hyperons in a neutron star based on the relativistic mean field approach. For nuclear matter below 1.5 times the normal nuclear density we constrain the model parameters by using the symmetric nuclear matter properties and theoretical investigations for neutron matter in the literature. We then extend the model to higher densities by including hyperons and isoscalar vector mesons that contain strangeness degree of freedom. We confirm that the  $\phi$  meson induces a  $\Lambda$  repulsive force and hardens the equation of state. The hardening arising from the  $\phi$  meson compensates the softening from the existence of hyperons. The flavor SU(3) and spin-flavor SU(6) relations are examined as well. We found that the coupling constants fitted by neutron matter properties could yield high enough maximum mass of a neutron star and the obtained results satisfy both the mass and radius constraints. The onset of the hyperon direct Urca process in neutron stars is also investigated using our approximation.

DOI: 10.1103/PhysRevD.97.023010

Discussed one of the major physics cases investigated at J-PARC: Hyperon Puzzle

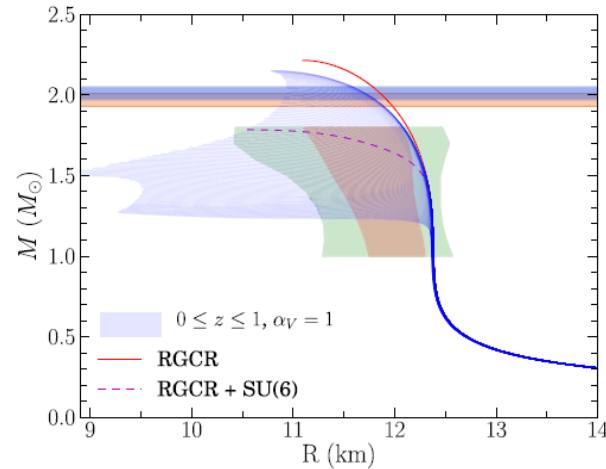


FIG. 10. Mass and radii curves with the variation of  $z$  with  $\alpha_V = 1$  in the RGCR model, i.e., case II. The red solid line is the result of the model in the SU(2) case and the dashed line is that of case I.

## $\bar{K} + N \rightarrow K + \Xi$ reaction and $S = -1$ hyperon resonances

Benjamin C. Jackson,<sup>1</sup> Yongseok Oh,<sup>2,3,\*</sup> H. Haberzettl,<sup>4,†</sup> and K. Nakayama<sup>1,5,‡</sup>

<sup>1</sup>*Department of Physics and Astronomy, The University of Georgia, Athens, GA 30602, USA*

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<sup>4</sup>*Institute for Nuclear Studies and Department of Physics, The George Washington University, Washington, DC 20052, USA*

<sup>5</sup>*Institut für Kernphysik and Center for Hadron Physics, Forschungszentrum Jülich, 52425 Jülich, Germany*

(Received 4 March 2015; revised manuscript received 17 May 2015; published 25 June 2015)

The  $\bar{K} + N \rightarrow K + \Xi$  reaction is studied for center-of-momentum energies ranging from threshold to 3 GeV in an effective Lagrangian approach that includes the hyperon  $s$ - and  $u$ -channel contributions as well as a phenomenological contact amplitude. The latter accounts for the rescattering term in the scattering equation and possible short-range dynamics not included explicitly in the model. Existing data are well reproduced and three above-the-threshold resonances were found to be required to describe the data, namely, the  $\Lambda(1890)$ ,  $\Sigma(2030)$ , and  $\Sigma(2250)$ . For the latter resonance we have assumed the spin-parity of  $J^P = 5/2^-$  and a mass of 2265 MeV. The  $\Sigma(2030)$  resonance is crucial in achieving a good reproduction of not only the measured total and differential cross sections but also the recoil polarization asymmetry. More precise data are required before a more definitive statement can be made about the other two resonances, in particular, about the  $\Sigma(2250)$  resonance that is introduced to describe a small bump structure observed in the total cross section of  $K^- + p \rightarrow K^+ + \Xi^-$ . The present analysis also reveals a peculiar behavior of the total cross-section data in the threshold energy region in  $K^- + p \rightarrow K^+ + \Xi^-$ , where the  $P$  and  $D$  waves dominate instead of the usual  $S$  wave. Predictions for the target-recoil asymmetries of the  $\bar{K} + N \rightarrow K + \Xi$  reaction are also presented.

DOI: 10.1103/PhysRevC.91.065208

PACS number(s): 13.75.Jz, 13.60.Rj, 13.88.+e, 14.20.Jn

Pointed out the importance of the experimental data from J-PARC and other experimental facilities.

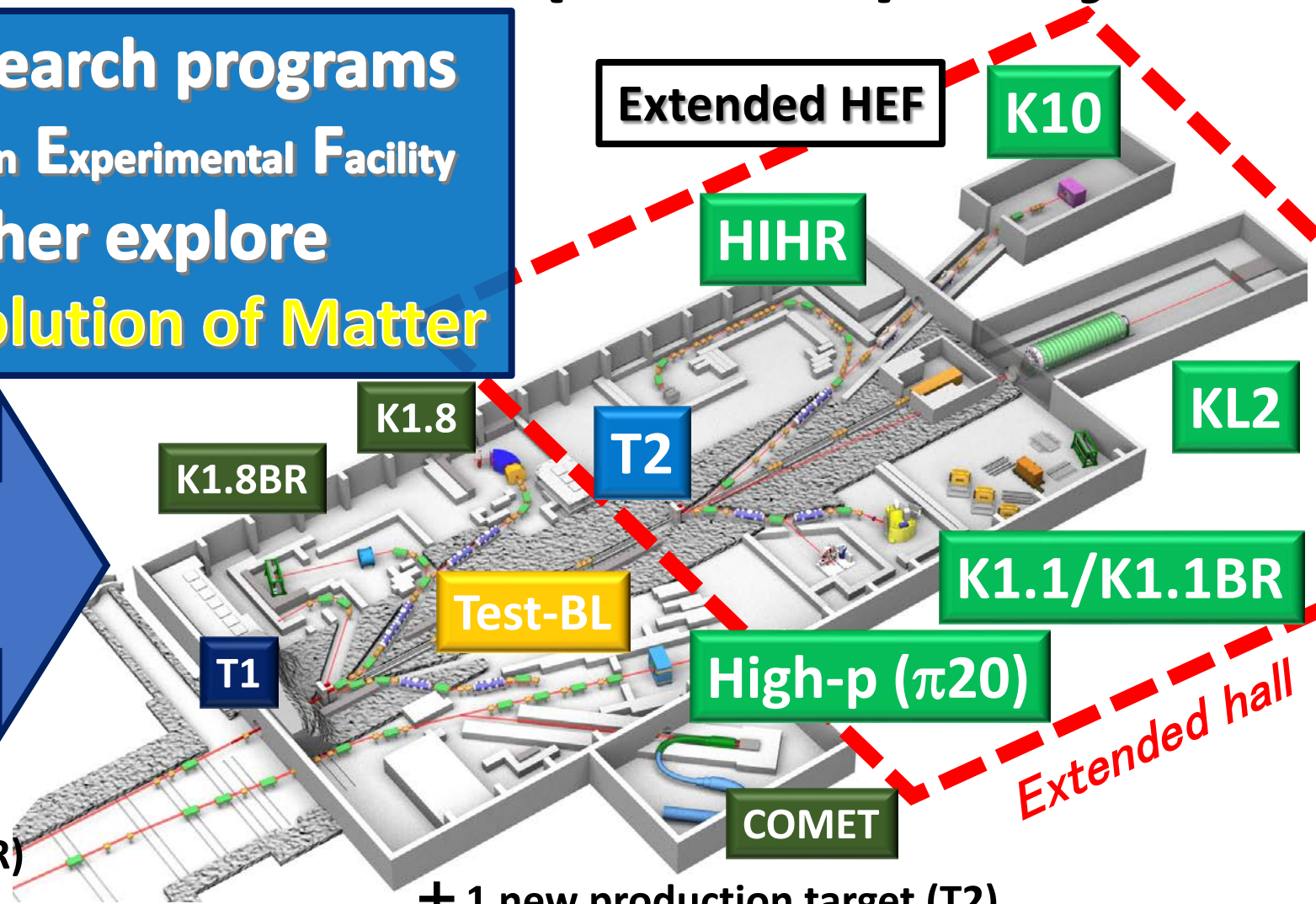
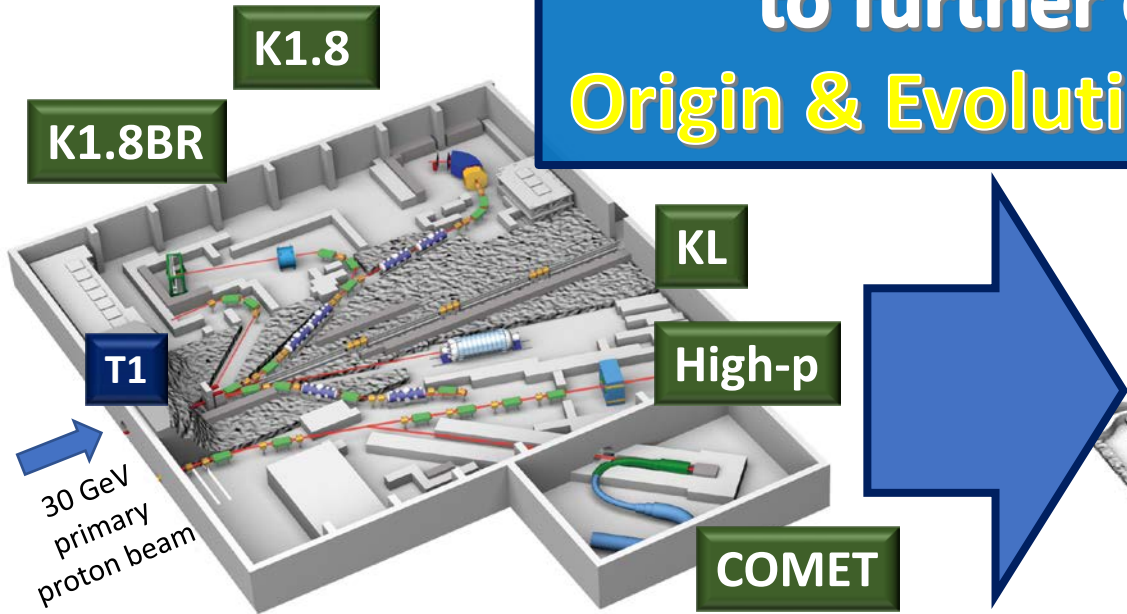


# Hadron Experimental Facility eXtension (HEF-ex) Project

expand research programs  
at the Hadron Experimental Facility  
to further explore  
**Origin & Evolution of Matter**

Present HEF  
(2009~)

Extended HEF



- 1 production target (T1)
- 1 secondary-charged beamline (K1.8/K1.8BR)
- 1 neutral beamline (KL)
- 1 primary beamline (High-p)
- 1 muon beamline (COMET)

- + 1 new production target (T2)
- + 4 new beamlines (HIHR, K1.1/K1.1BR, KL2, K10)
- + 2 updated beamlines (High-p ( $\pi 20$ ), Test-BL)

# 3rd International WS on the Extension Project for the J-PARC Hadron Experimental Facility (3rd J-PARC HEF-ex WS), Mar.14-16 2023, J-PARC



# Kbar-N scattering for $\Xi$ production

Yongseok Oh (Kyungpook National University, Korea)

3rd International Workshop on the Extension Project for the J-PARC Hadron Experimental Facility  
2023. 3. 14 - 3.16, J-PARC, Tokai, Japan

- $\Xi$  production as a probe to study hyperon resonances of  $S=-1$
- $\Xi$  spectrum to understand hyperon structure
- Theoretical investigation of the reactions for  $\Xi$  production

$$\gamma N \rightarrow KK\Xi \text{ (JLab)} \quad \bar{K}N \rightarrow K\Xi \text{ (J-PARC)}$$

$$p\bar{p} \rightarrow \Xi\bar{\Xi} \text{ (FAIR)} \quad \pi N \rightarrow KK\Xi \text{ (J-PARC)}$$

- Extension of  $\Xi$  production to  $\Xi^*$  production

Hadron Hall Users' Association  
Write-ups for workshop on the project for the extended hadron experimental facility of J-PARC  
Partial collection of LOIs at the extended hadron hall and the related topics  
Date: March 5, 2021  
Proposal for JLab PAC48  
Strange Hadron Spectroscopy with Secondary  $K_L$  Beam in Hall D

**Experimental Support:**  
Shankar Adhikari<sup>1</sup>, Meikov Amarian<sup>2</sup> (Contact Person, Spokesperson)<sup>1</sup>, Anshak Anurayan<sup>1</sup>, Alexander Anuzgenov<sup>3</sup>, Marouen Badiouch<sup>4</sup>, Mikhail Baskakov<sup>5</sup> (Spokesperson)<sup>6</sup>, Vasily Baturin<sup>7</sup>, Vladimir Berdnikov<sup>1,8</sup>, Olga Cortes Becerra<sup>9</sup>, Timothy Black<sup>10</sup>, Werner Bregler<sup>11</sup>, William Brune<sup>12</sup>, William Brooks<sup>13</sup>, Volker Brueker<sup>14</sup>, Eugene Chudakov<sup>15</sup>, Gerard Clark<sup>16</sup>, Ehalp Cole<sup>17</sup>, Volker Crede<sup>18</sup>, Donald Day<sup>19</sup>, Pavel Degtyarev<sup>20</sup>, Alexandre Deur<sup>21</sup>, Sean Dobbs<sup>22</sup> (Spokesperson)<sup>23</sup>, Gail Dodge<sup>24</sup>, Anatoly Dolgolenko<sup>25</sup>, Simon Edelmann<sup>26</sup>, Hovsep Egriyan<sup>27</sup> (Lab Contact Person)<sup>28</sup>, Denis Epifanov<sup>29</sup>, Paul Eugenio<sup>30</sup>, Stuart Fegan<sup>31</sup>, Aleksandra Filipic<sup>32</sup>, Sergey Furterov<sup>33</sup>, Lutz Gai<sup>34</sup>, Franco Garibaldi<sup>35</sup>, Ashot Gasparian<sup>36</sup>, Gagik Gevorkian<sup>37</sup>, Derek Glazier<sup>38</sup>, Colin Gleason<sup>39</sup>, Vladimir Goryachev<sup>40</sup>, Lei Guo<sup>41</sup>, David Hamblin<sup>42</sup>, Avenk Hayrapetyan<sup>43</sup>, Garth Huber<sup>44</sup>, Andrew Hurley<sup>45</sup>, Charles Hyde<sup>46</sup>, Isabella Ilan<sup>47</sup>, David Inland<sup>48</sup>, Igal Jaeger<sup>49</sup>, Kyungwon Jo<sup>50</sup>, Yusek Kikoyari<sup>51</sup>, Giorgos Kikyo<sup>52</sup>, Mohamed Kamel<sup>53</sup>, Christopher Kent<sup>54</sup>, Chan Wook Kim<sup>55</sup>, Eberhard Klomp<sup>56</sup>, Geoffrey Krauss<sup>57</sup>, Sebastian Kuhn<sup>58</sup>, Sergey Kulechov<sup>59</sup>, Alexander Luger<sup>60</sup>, Ilya Lutsa<sup>61</sup>, David Lawrence<sup>62</sup>, Daniel Lerauch<sup>63</sup>, Wenkang Li<sup>64</sup>, Ervin Lucht<sup>65</sup>, Valery Lyubovitskiy<sup>66,67,68</sup>, David Mac<sup>69</sup>, Michael McCulligan<sup>70</sup>, Mark Maslov<sup>71</sup>, Hrachya Mkrtchyan<sup>72</sup>, Vladimir Mironov<sup>73</sup>, Mihai Mousine<sup>74</sup>, Václav Mokev<sup>75</sup>, Curtis Meyer<sup>76</sup>, Bryan McEminon<sup>77</sup>, Frank Nerling<sup>78</sup>, Matthew Nicol<sup>79</sup>, Gabriel Niculescu<sup>80</sup>, Alexander Oboznenko<sup>81</sup>, Zass Papandreou<sup>82</sup>, Ki Jun Park<sup>83</sup>, Eugene Paryuk<sup>84</sup>, Peter Paul<sup>85</sup>, Lubomir Pecher<sup>86</sup>, Willi am Piepke<sup>87</sup>, John Pisk<sup>88</sup>, Jang Rahnbold<sup>89</sup>, James Ritman<sup>90</sup> (Spokesperson)<sup>91</sup>, Danuta Romanov<sup>92</sup>, Carlos Salgado<sup>93</sup>, Todd Saragaga<sup>94</sup>, Susan Schachmand<sup>95</sup>, Amy Schertz<sup>96</sup>, Axel Schenzel<sup>97</sup>, Daniel Sobier<sup>98</sup>, Alexander Sotnikov<sup>99</sup>, Sergei Stetsov<sup>100</sup>, Justin Stevens<sup>101</sup> (Spokesperson)<sup>102</sup>, Igor Strakovsky<sup>103</sup> (Spokesperson)<sup>104</sup>, Victor Tanasoaie<sup>105</sup>, Sumon Tayari<sup>106</sup>, Anzika Theil<sup>107</sup>, Oana Maria Ursescu<sup>108</sup>, Holly Suzanne Vance<sup>109</sup>, Daniel Wyatt<sup>110</sup>, Lawrence Weinstein<sup>111</sup>, Timothy Whittaker<sup>112</sup>, Nianga Wolkanarschich<sup>113</sup>, Bogdan Wojcikowski<sup>114</sup>, Nicholas Zachariou<sup>115</sup>, Jonathan Zetang<sup>116</sup>, Xue Zhang<sup>117</sup>

**Theoretical Support:**  
Alexy Anasievich<sup>118</sup>, Aleksei Bazarov<sup>119</sup>, Denis Belyaev<sup>120</sup>, Veronique Bernard<sup>121</sup>, Gilberto Colangelo<sup>122</sup>, Alek Chepur<sup>123</sup>, Michael Doring<sup>124</sup>, Ali Ekanedanz<sup>125</sup>, Jose Ochoa<sup>126</sup>, Helmut Haberzettl<sup>127</sup>, Mirza Hadzimalmedovska<sup>128</sup>, Robert Jaffe<sup>129</sup>, Boris Kuptsovich<sup>130</sup>, Henrich Leutwyler<sup>131</sup>, Maxim Mas<sup>132</sup>, Terry Maier<sup>133</sup>, Maxim Matveev<sup>134</sup>, Ulf-G. Meißner<sup>135</sup>, Colin Morningstar<sup>136</sup>, Bachir Moussallam<sup>137</sup>, Kazuo Nakayama<sup>138</sup>, Wolfgang Ochs<sup>139</sup>, Youngseok Oh<sup>140</sup>, Rifat Omarovic<sup>141</sup>, Hedim Osmanovic<sup>142</sup>, Eulogio Oset<sup>143</sup>, Anirban Palit<sup>144</sup>, Jose Pelaez<sup>145</sup>, Alessandro Pilloni<sup>146</sup>, Maxim Polyakov<sup>147</sup>, David Richards<sup>148</sup>, Arkatz Rodas<sup>149</sup>, Dan-Oliv Ruzic<sup>150</sup>, Jaume Ruiz de Elvira<sup>151</sup>, Hui-Young Ryu<sup>152</sup>, Elena Santopinto<sup>153</sup>, Andrey Savin<sup>154</sup>, Jugoslav Stokich<sup>155</sup>, Albert Starin<sup>156</sup>, Adam Szczepaniak<sup>157</sup>, Ronald Workman<sup>158</sup>, Bing-Song Zou<sup>159</sup>

Hadron Hall Users' Association (HUA)  
2019/June

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# Prof. Oh's activities extended even for EIC

## NCU workshop on EIC physics and detectors

2022  
12/9 Fri. ▶ 10 Sat.

National Central University

### Organization Committee:

Jen-Chieh Peng(UIUC/NCU),  
Wen-Chen Chang(AS),  
Chia-Ming Kuo(NCU)



# Korean EIC & J/ψ Photoproduction

Yongseok Oh  
(Kyungpook National University)

Asia Pacific Center for Theoretical  
Physics (APCTP)

- A hub for our activities

NCU Workshop on EIC Physics and Detectors, National Central University, Dec. 9 - 10, 2022

3

Potential Korean  
involvement for EIC



From Yongsun Kim's slides

J/ψ Photoproduction off Nucleons

T.-S. H. Lee, S. Sakinah, Y. Oh, arXiv:2210.02154, to be published in Eur. Phys. J. A

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I would like to offer my deepest condolences.  
We, the hadronic physics community, miss  
Professor Yongseok Oh forever.

