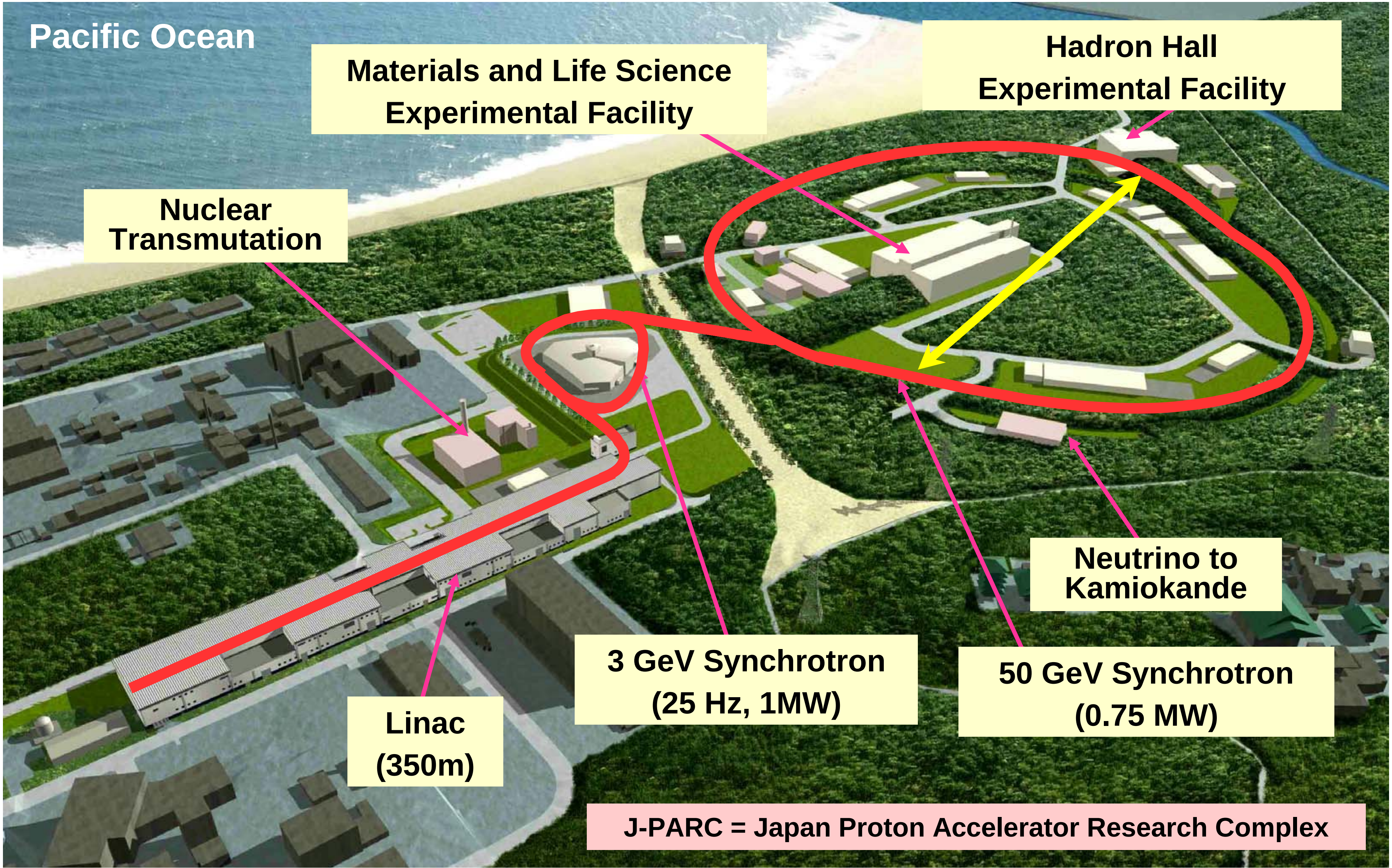
20-26 July, 2008
SPIN and SYMMETRY 2008 in Praha

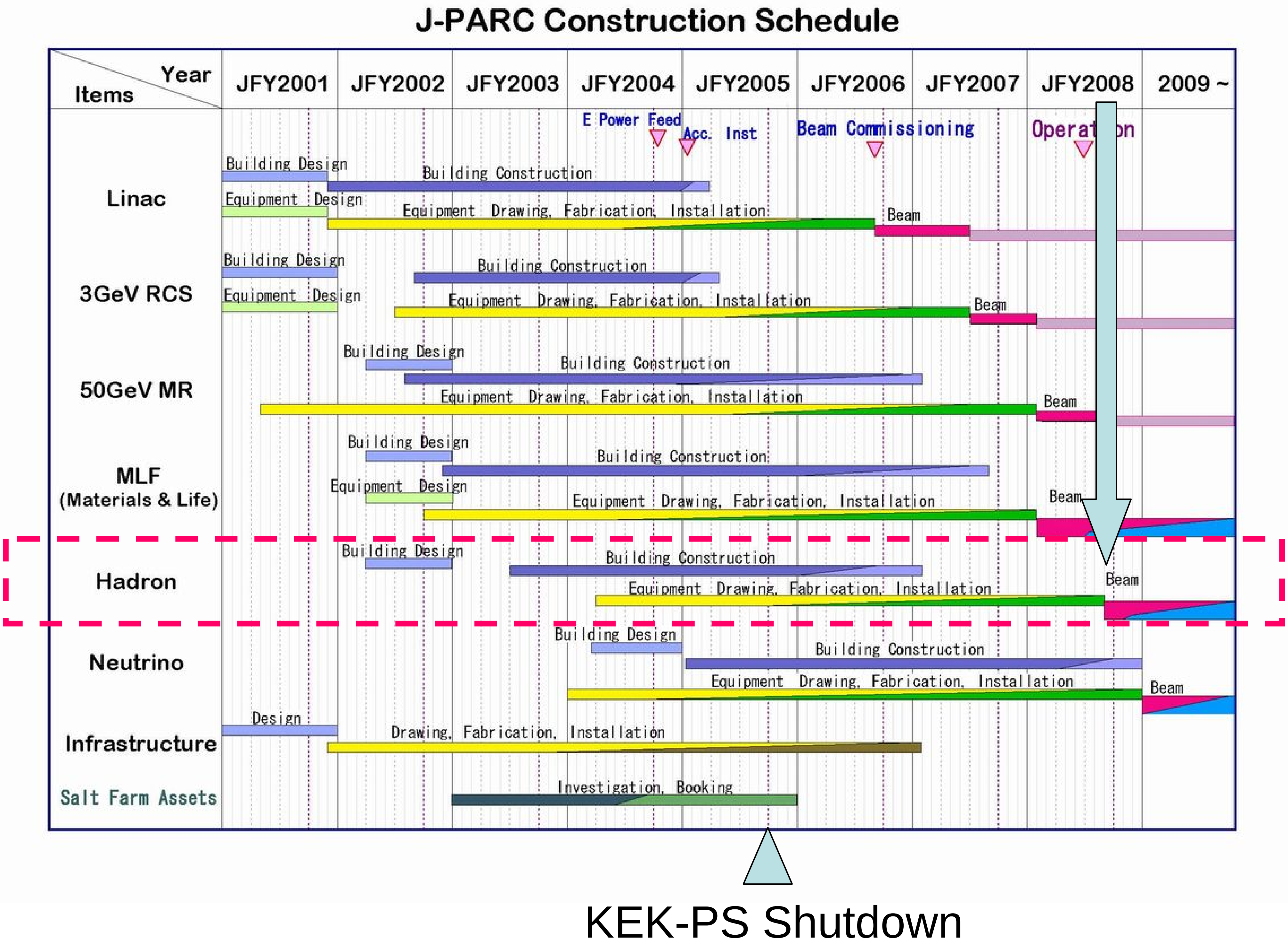
Experimental Plans at the J-PARC Hadron Experimental Hall

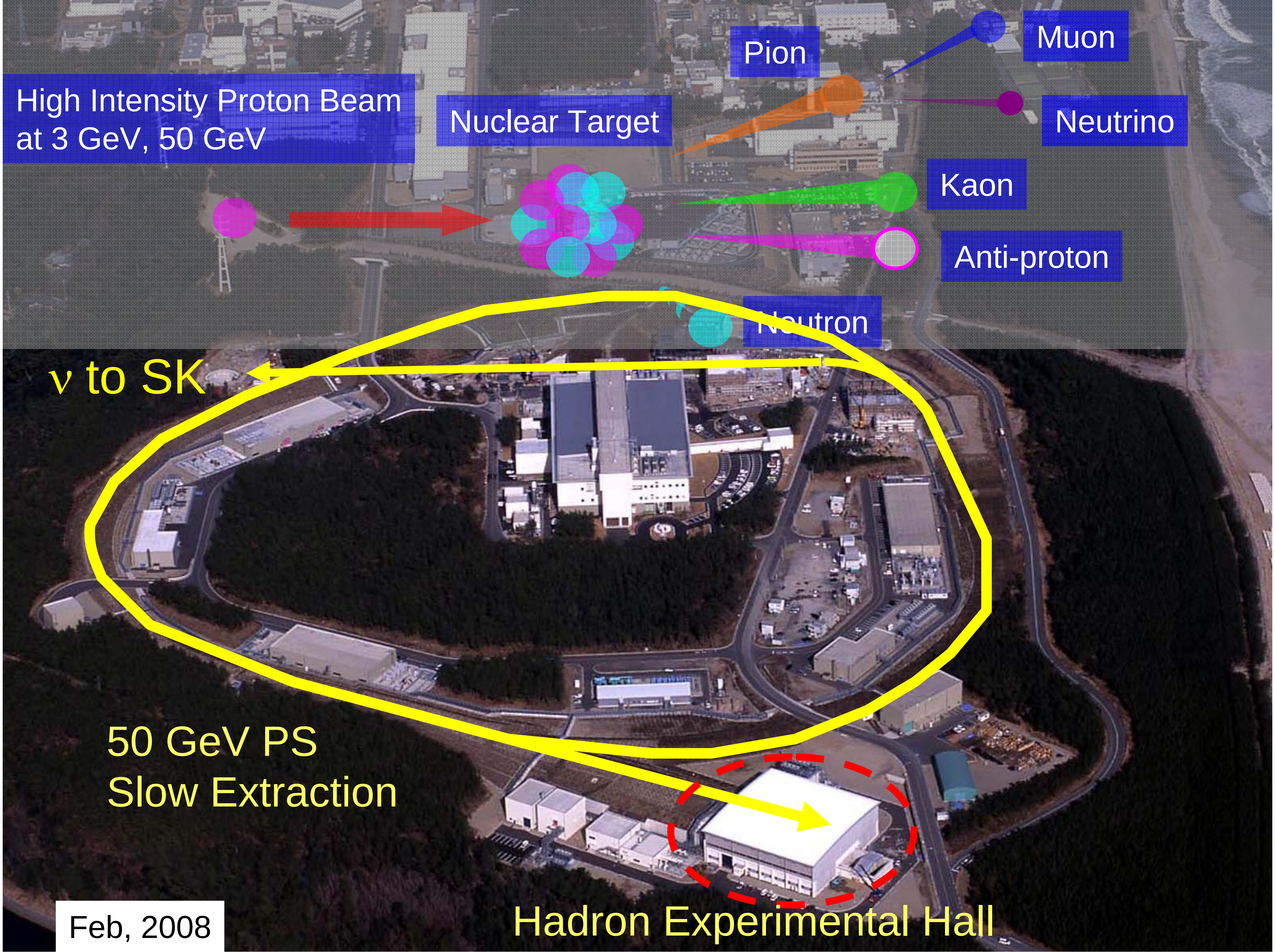
Hiroyuki Noumi,
Research Center for Nuclear Physics,
Osaka University

Contents:

J-PARC *for High Power Proton Beam of ~Mega Watt*

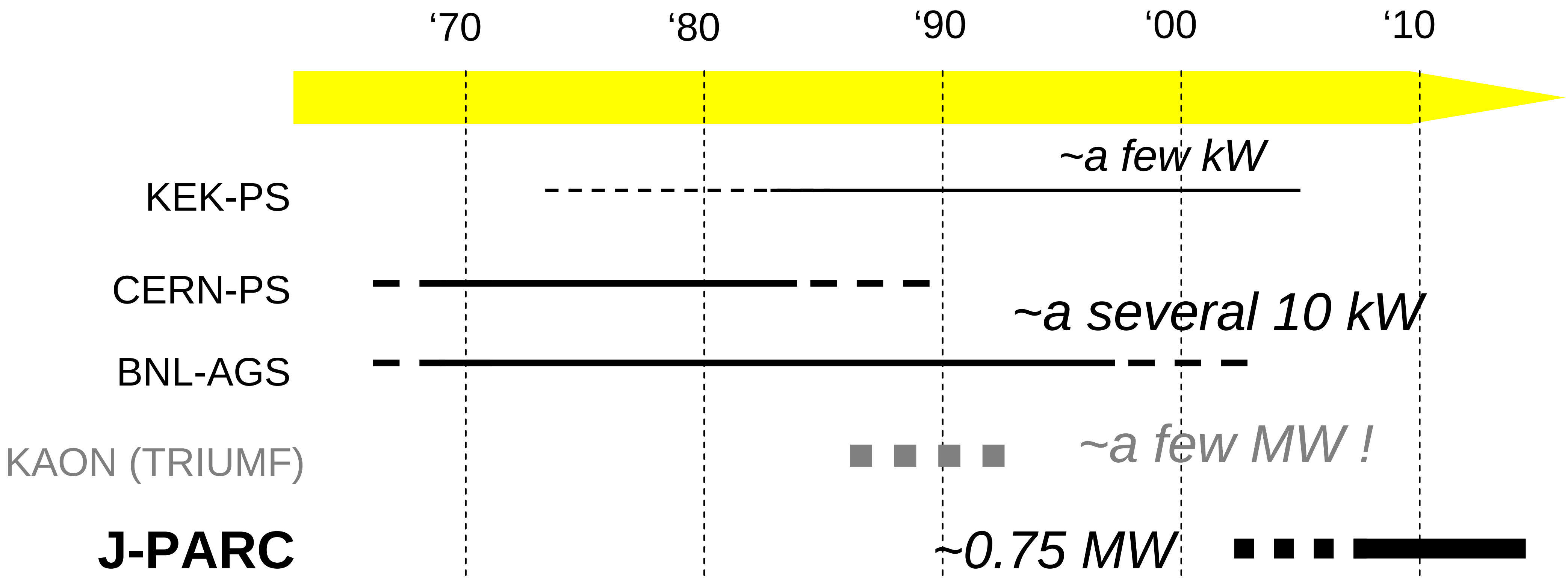



J-PARC Construction Schedule
Year
Items
JFY2001
JFY2002
JFY2003
JFY2004
JFY2005
JFY2006
JFY2007
JFY2008
2009 ~
E Power Feed
Acc. Inst
Beam Commissioning
Operation
Linac
Building Design
Building Construction
Equipment Design
Equipment Drawing, Fabrication, Installation
Beam
3GeV RCS
Building Design
Building Construction
Equipment Design
Equipment Drawing, Fabrication, Installation
Beam
50GeV MR
Building Design
Building Construction
Equipment Drawing, Fabrication, Installation
Beam
MLF
(Materials & Life)
Building Design
Building Construction
Equipment Design
Equipment Drawing, Fabrication, Installation
Beam
Hadron
Building Design
Building Construction
Equipment Drawing, Fabrication, Installation
Beam
Neutrino
Building Design
Building Construction
Equipment Drawing, Fabrication, Installation
Beam
Infrastructure
Design
Drawing, Fabrication, Installation
Salt Farm Assets
Investigation, Booking
KEK-PS Shutdown

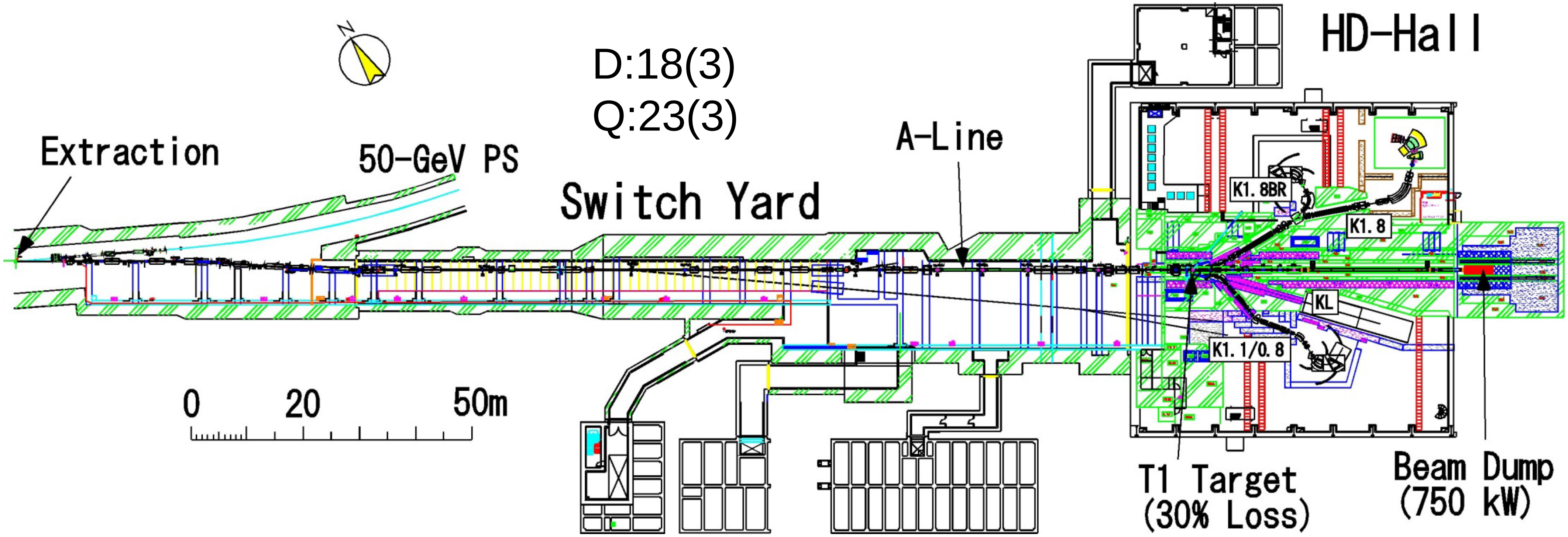

High Intensity Proton Beam at 3 GeV, 50 GeV
Nuclear Target
Pion
Muon
Neutrino
Kaon
Anti-proton
Neutron
ν to SK
50 GeV PS
Slow Extraction
Hadron Experimental Hall
Feb, 2008

The Hadron Experimental Hall (HD-Hall)
is
Only and World Highest Power
of

the KAON Factory



HADRON BEAM LINE FACILITY



- Slow Extraction Beam :
  - 50 GeV 15 μA (0.75 MW)
    3.3×10^{14} p/spill (0.7 s flat top, 3.6 s repetitio
  - 30 GeV, 9μA (0.27 MW) in Phase 1

x100 of KEK PS
x10 of BNL AGS

- Key Issue for **safe** and **stable** operation of the beam line
  - ✓ Minimum Un-necessary/Unwanted Beam Loss
  - ✓ Radiation-Hardness and/or Heat-resistance for Beam Line Components
  - ✓ Maintenance Scenario in High Radiation Area

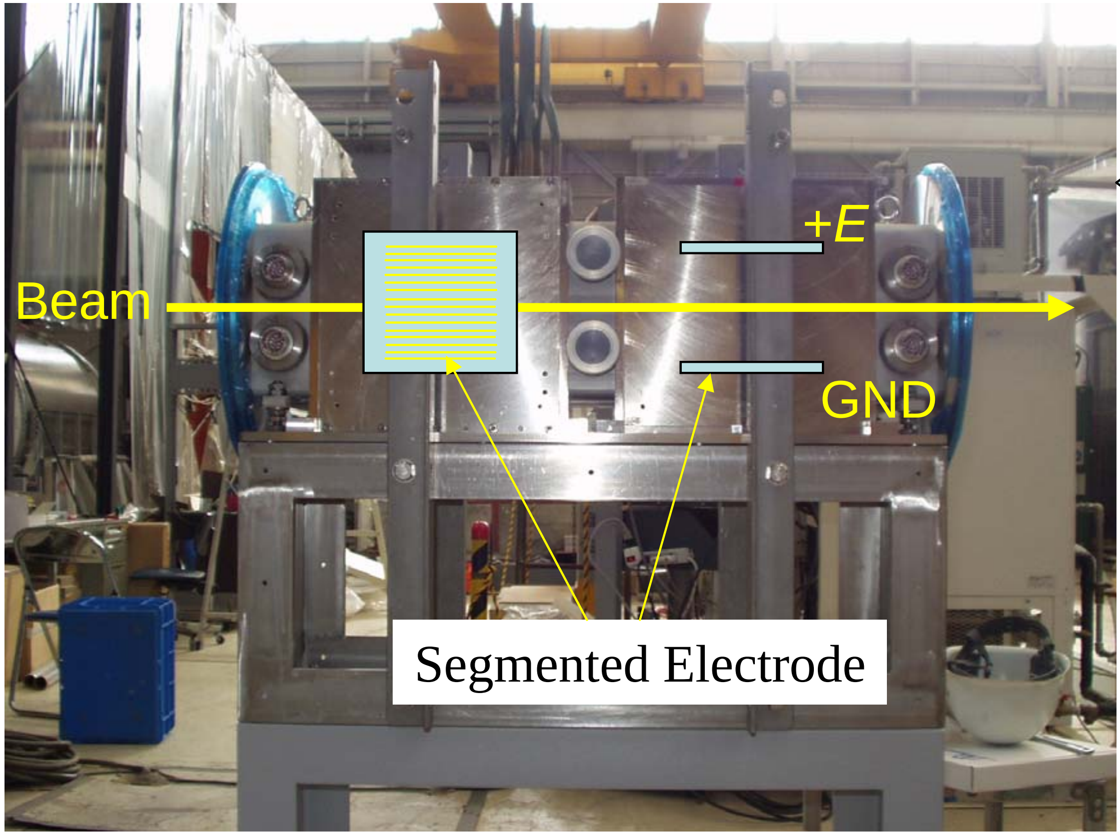
Key Instruments / Devices for High Power Beam Handling

◎ Completely Inorganic Electromagnet

- Coil w/ Mineral Insulation Cable
- Bi-metal Thermal Switch
- Ceramic Insulation Signal Line
- Water Pressure Gauge
- Metal or Graphite Foil Gasket

……

Radiation-Hard Magnet
(耐放射線電磁石)

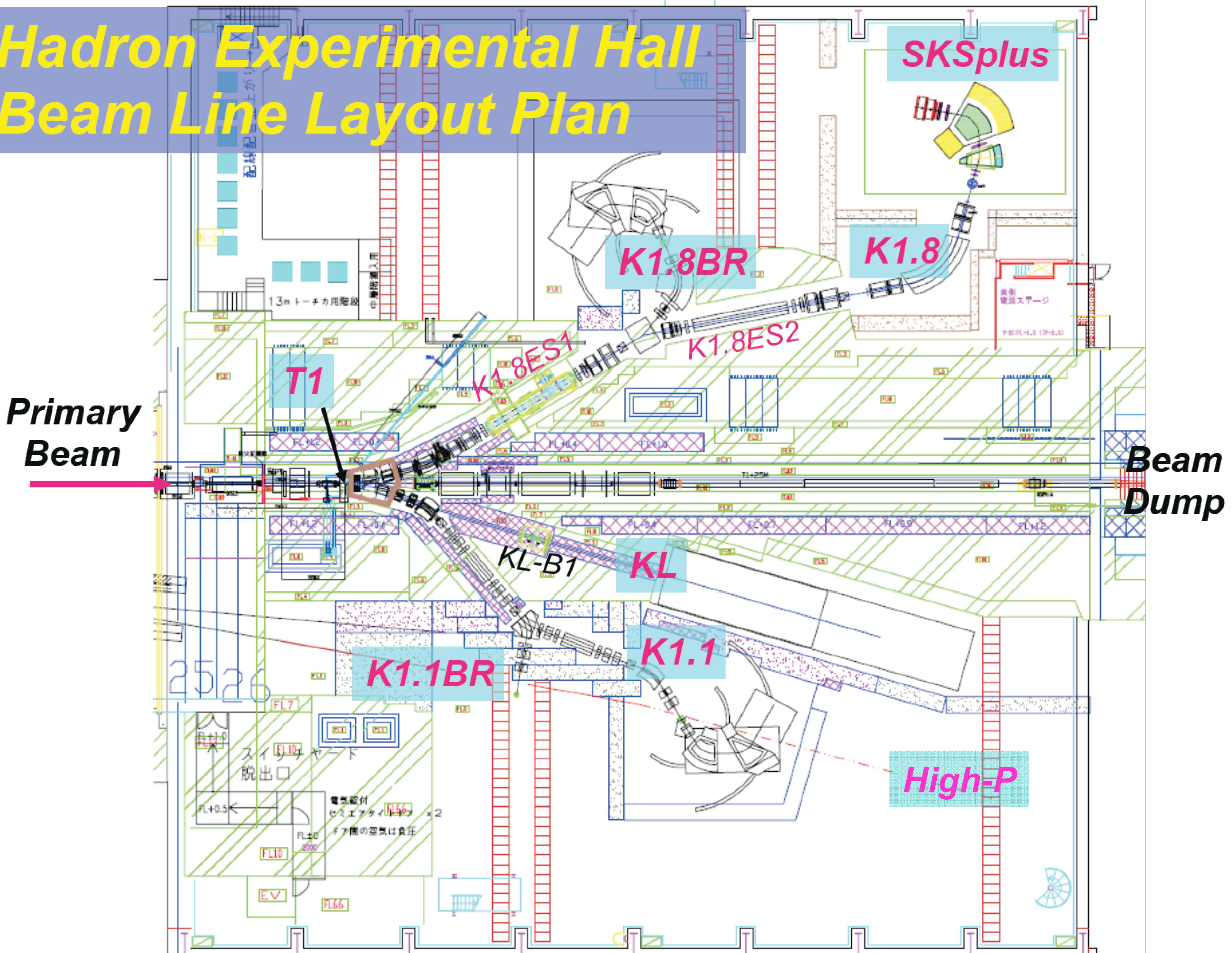


Segmented Electrode

◎ Non-Destructive Beam Diagnosis

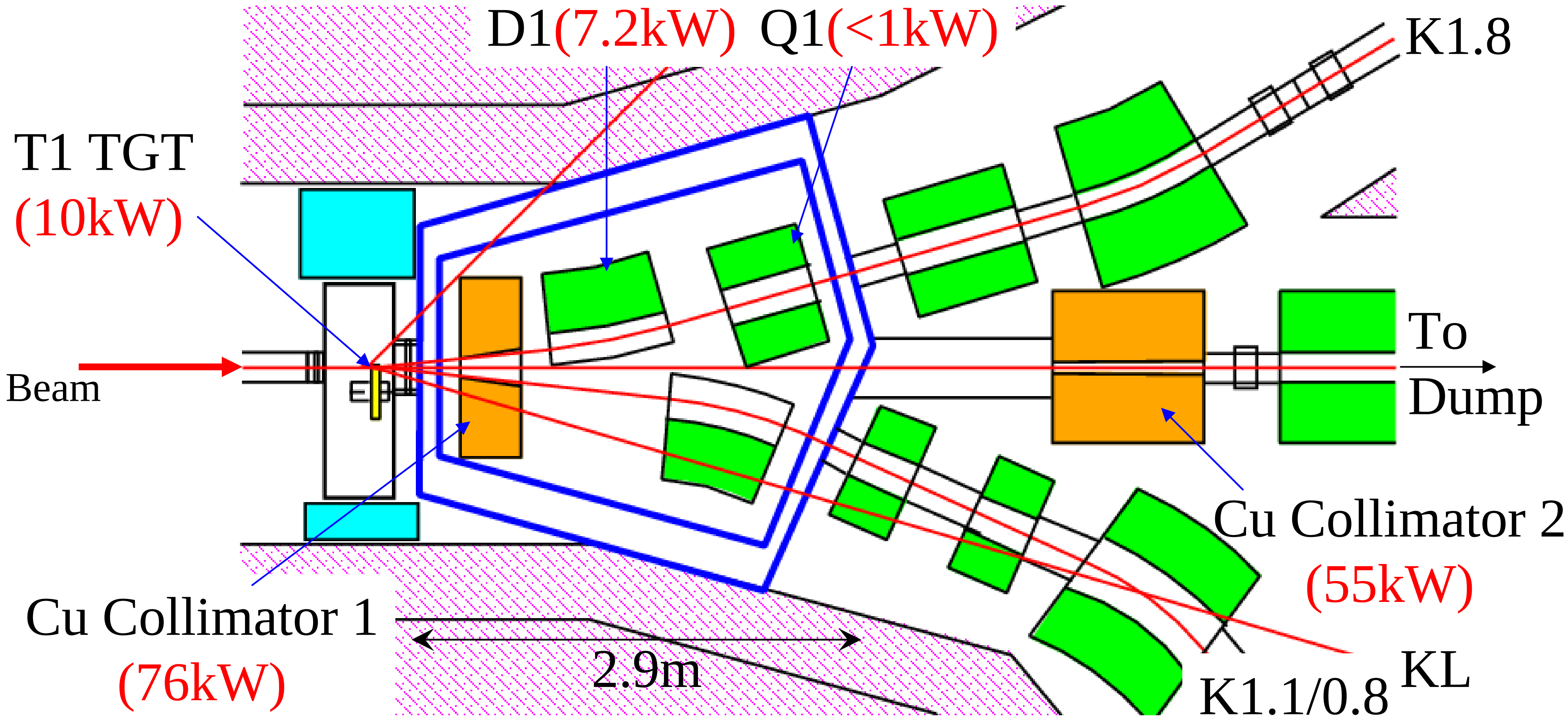
- Residual Gas Ionization
- Beam Profile/Beam Intensity
- No Electrode Intercept Beam
- No Beam Loss
- No Amplifier (Low Vacuum ~10Pa)
- Collection E Field
- e- Confining Magnetic Field

Hadron Experimental Hall Beam Line Layout Plan

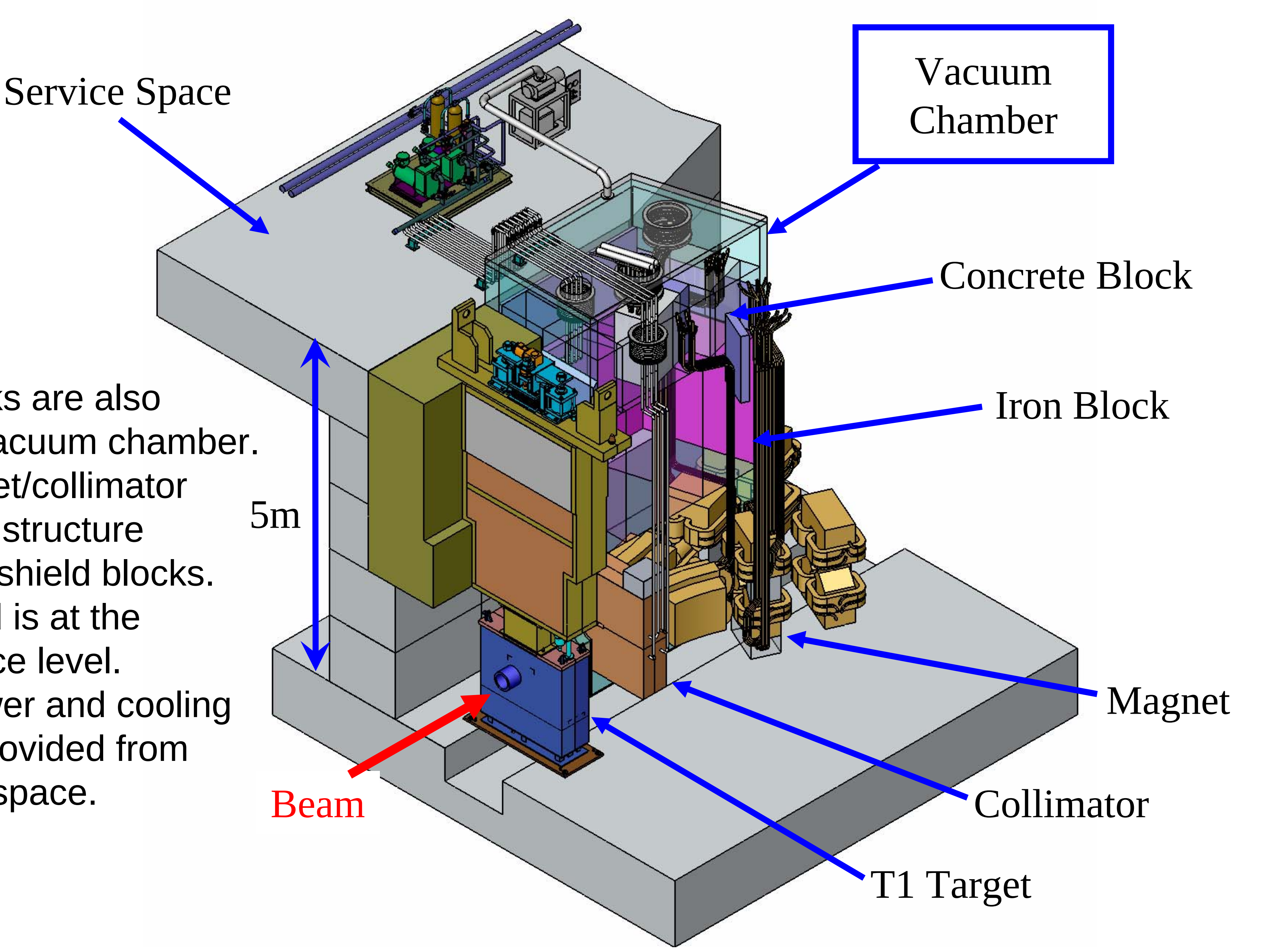


Energy Deposit arround the T1 Target

T1 (Ni t54mm) is irradiated with 50 GeV 15μA (0.75 MW) proton beam.
A power of 200 kW is released at T1.

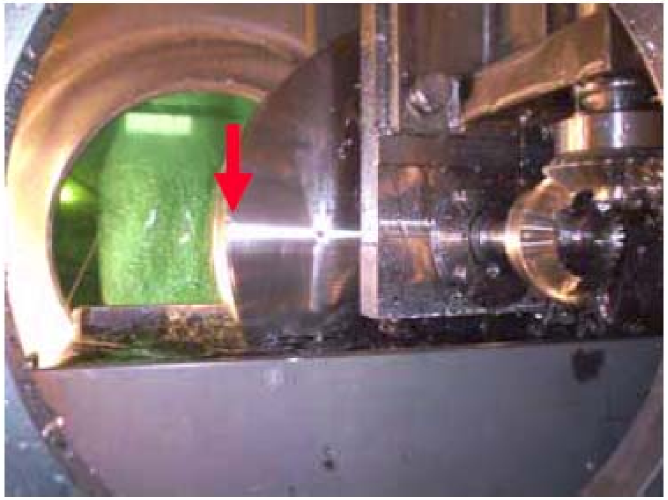


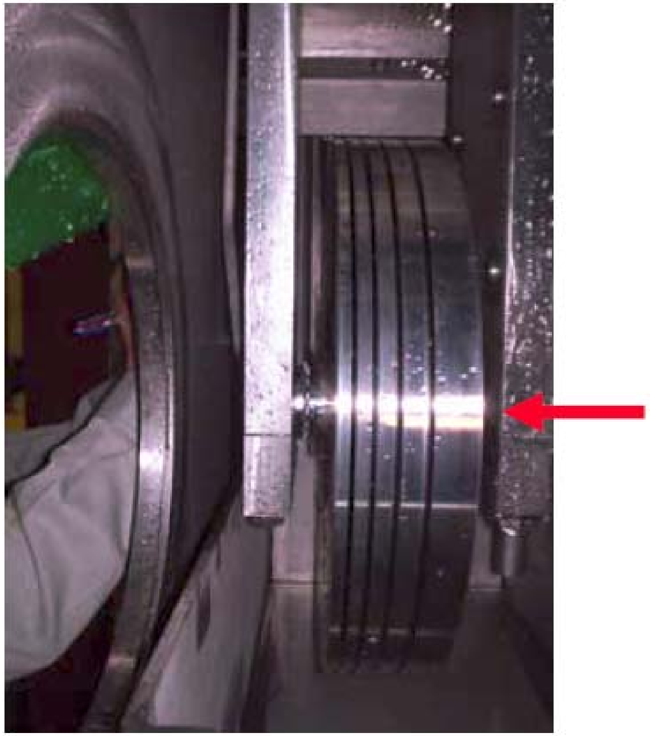
T1 and Vacuum Chamber

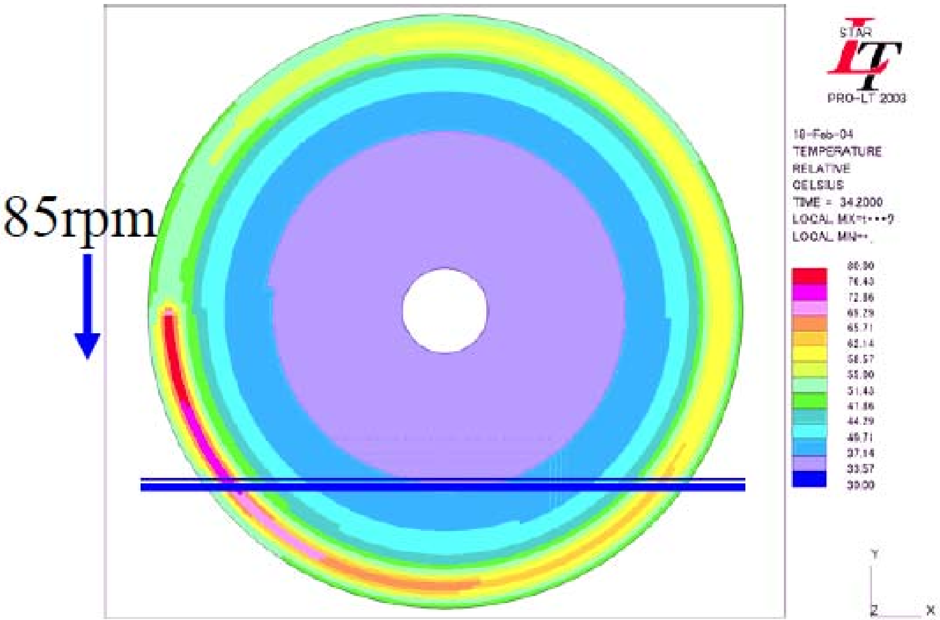


- Shield blocks are also inside the vacuum chamber.
- Each magnet/collimator has module structure unified with shield blocks.
- Chamber lid is at the service space level.
- Electric power and cooling water are provided from the service space.

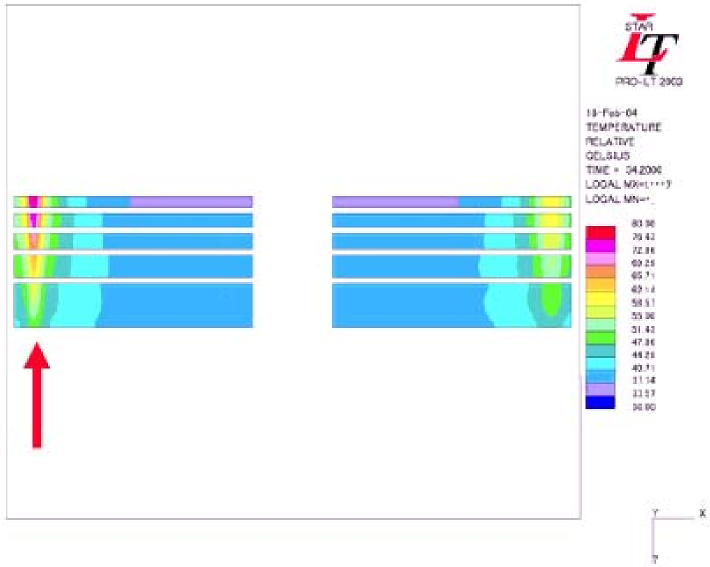
Water-cooled, Rotating Ni Disk Target



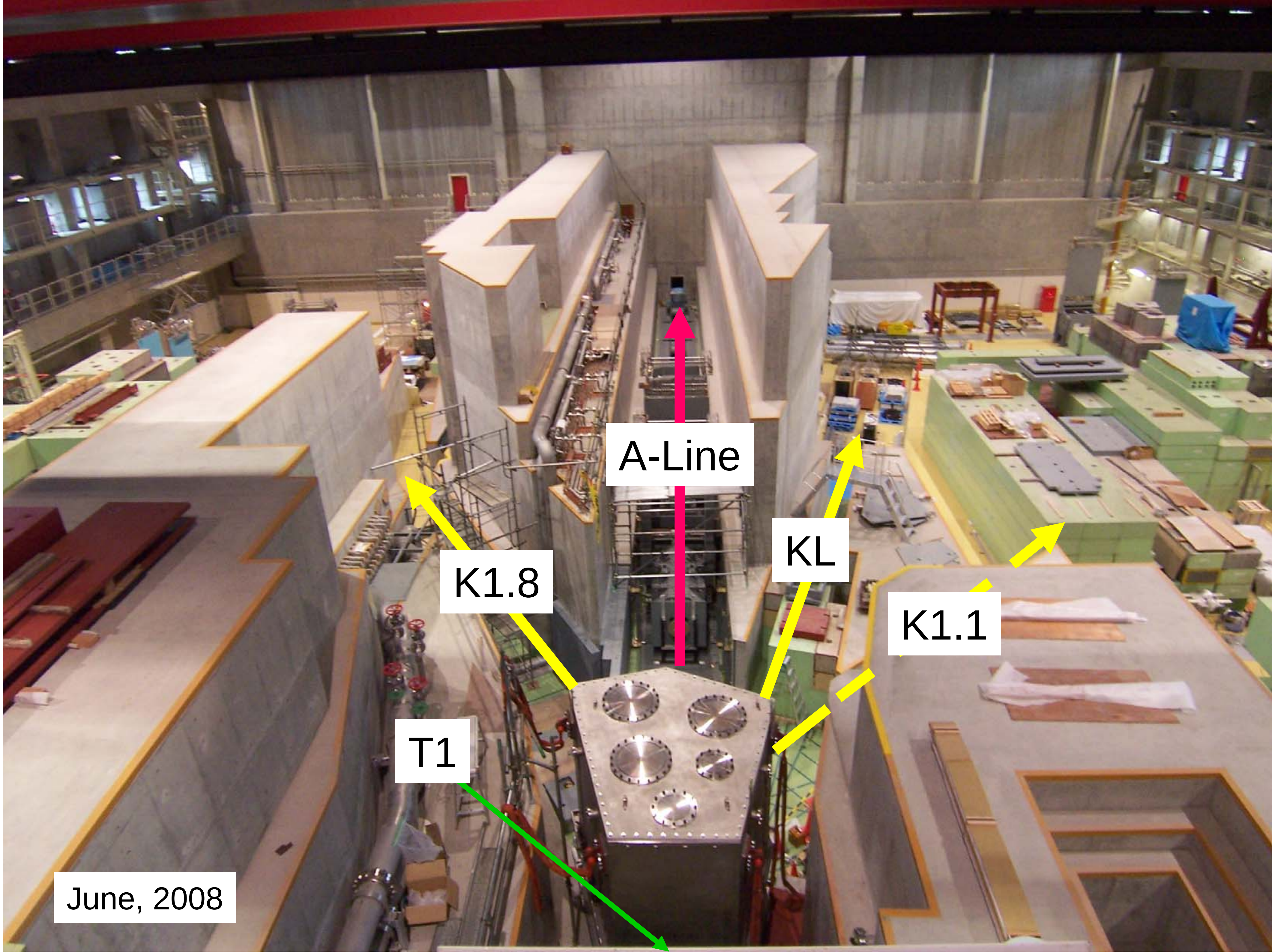




Temperature rise

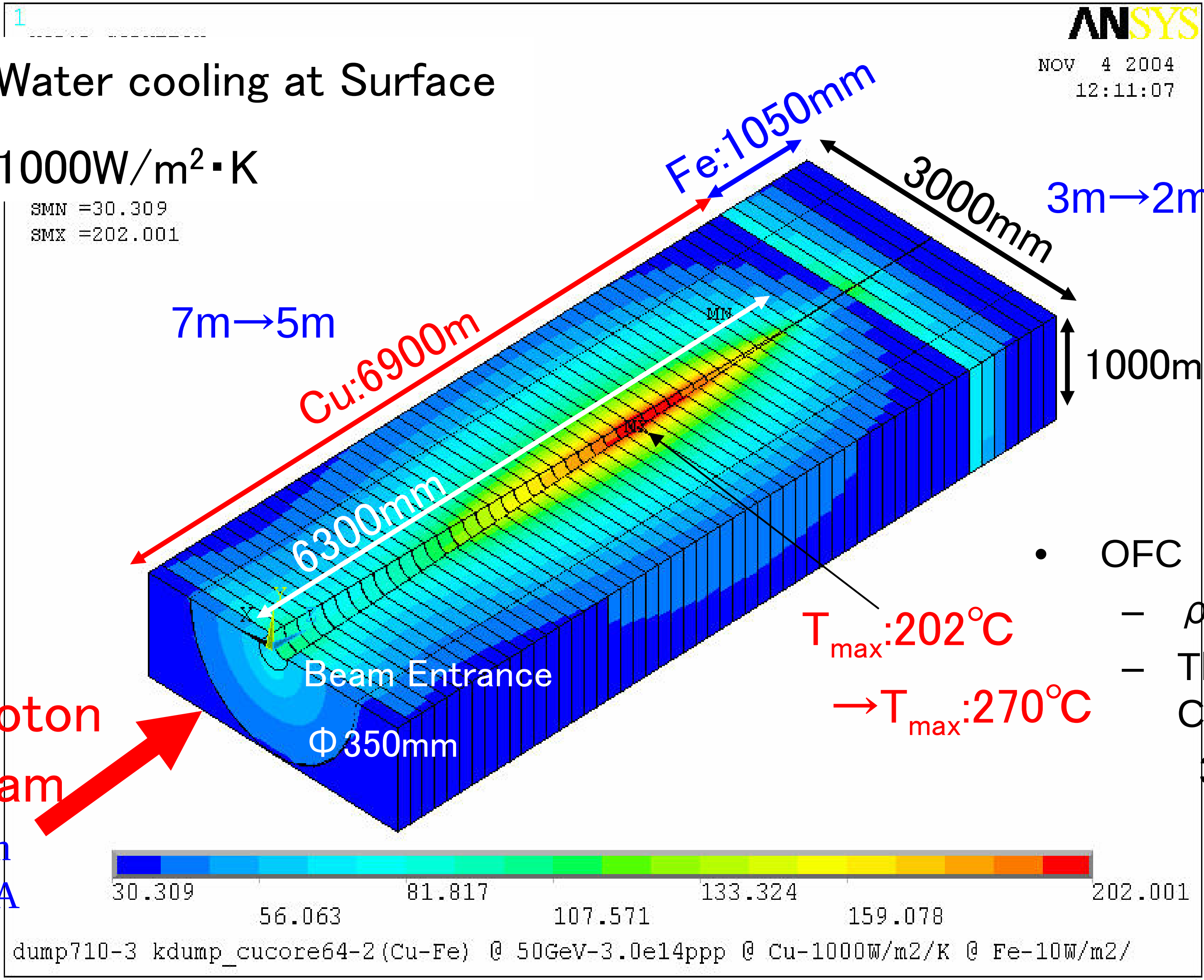


Design w/ Simulation and R&D w/ proof machine


A-Line
K1.8
KL
K1.1
T1
June, 2008

Beam Dump - Heat analysis by MARS & ANSYS

(calculated by A. TOYODA & M. MINAKAWA)



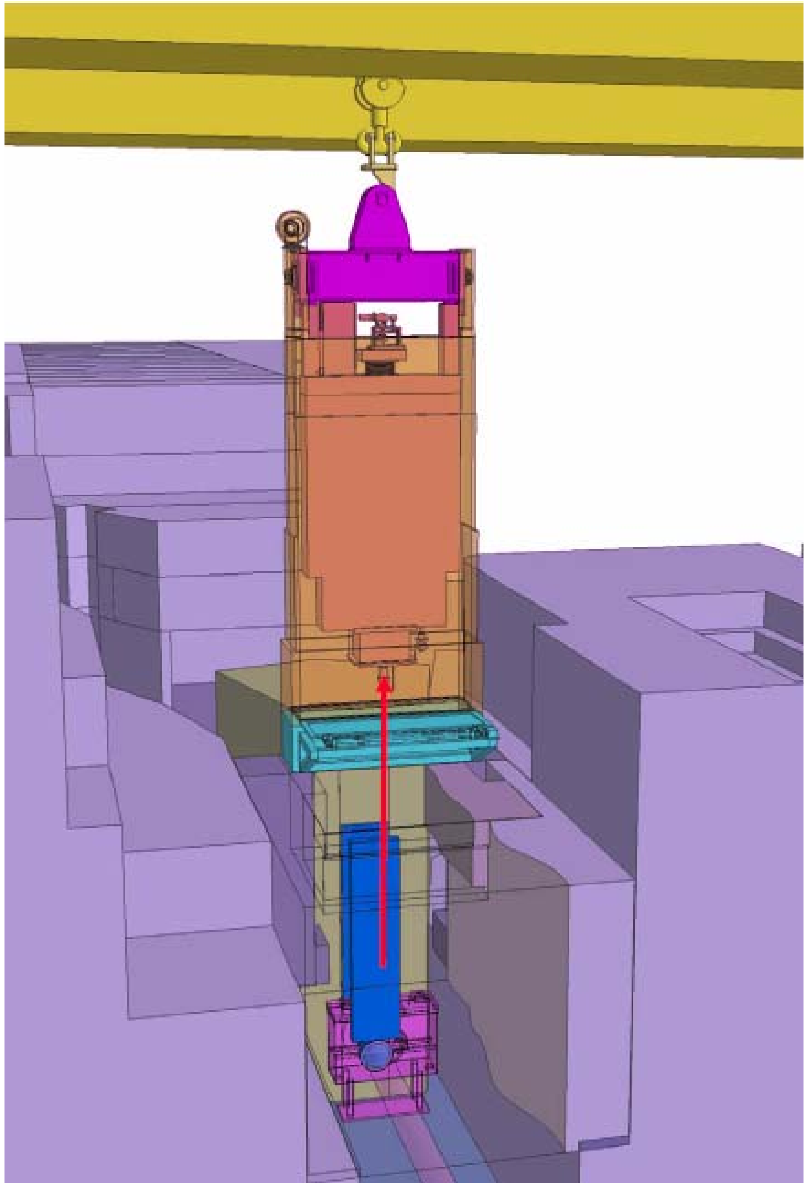
Proton beam
50GeV-15μA
(750kW)

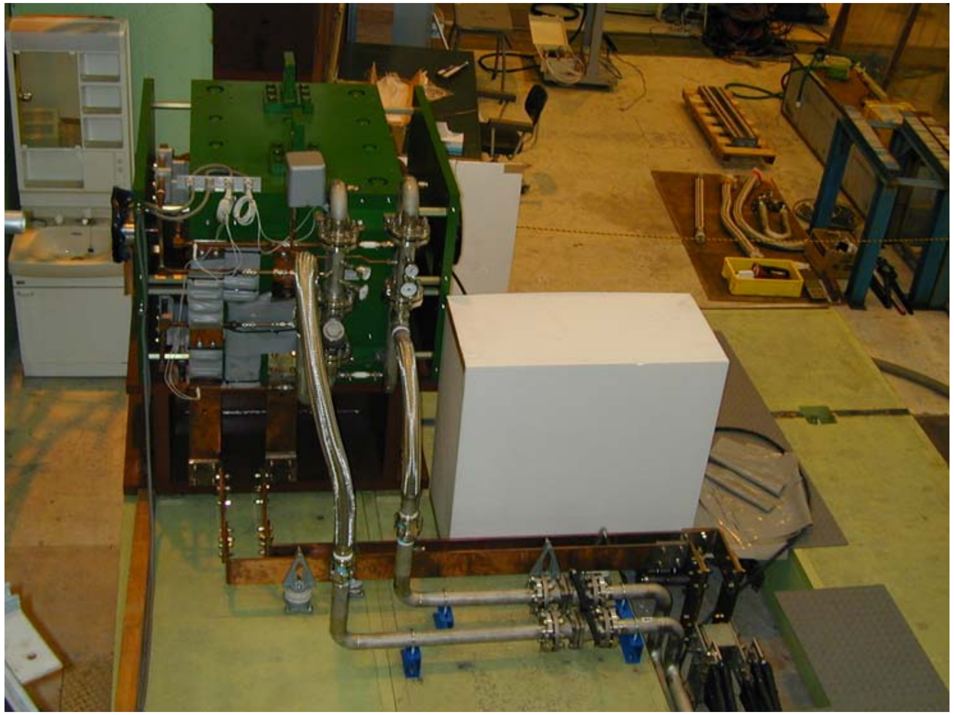
- OFC
  - ρ =8.9[g/cm³]
  - Thermal Conductivity 390 [W/m/K]

We finally reduced the volume of Cu.

Maintenance

Full Remote with crane and cask





Semi-Remote

- Quick Connection/Disconnection
  - ✓ Lever Coupler for Cooling Water (2MPa)
  - ✓ Knife Switch for Electricity (3000A)
  - ✓ Bellow Expander (Vacuum)
  - ✓ Chain Cramp for Vacuum Flange for U-tight Metal Seale

Design Concept :

To Layout secondary lines as many as possible,
while only one target station, T1, is constructed at the beginning.

- Two Separated Charged Kaon Beam Lines (K1.8 and K1.1)
  Branch Line of each BL (K1.8BR / K0.8)
- One Neutral Kaon Beam Lines (K0)

<u>Efficient coordination and execution of experimental programs</u>

Milestones

- July 2007: Start of magnet Inst. In HD-Hall
- Nov.2007: Start of Dry-run of 50GeV-PS(MR)
- Feb.2008: Inst. of Beam Abort Devices of MR
- May 2008: Beam commissioning of MR (at 3GeV)
- July 2008: Inst. of Slow Ext. Devices of MR ←
- Dec.2008: Beam commissioning of MR（upto 30GeV)
  Start of Slow Extraction
- Feb.2009: End of the first Slow Extraction
- April2009: Start of Neutrino Beam Operation
  with Fast Extraction
- Oct.2009: Second Slow Extraction for Physics

PAC Approval Summary

Jan, 2008

	(Co-)Spokespersons	Affiliation	Title of the experiment	Approval status (PAC recommendation)	Slow line priority		Beamline
					Day1?	Day1 Priority	
P01	V. Sumachev	Petersburg Nulear Physics Institute	Proposal on measurements of the spin rotation parameters A and R at the J-PARC in the resonance region of π-N elastic scattering	Rejected			
P03	K. Tanida	Kyoto U	Measurement of X rays from Ξ^- Atom	Stage 2			K1.8
P04	J. C. Peng; S. Sawada	U. of Illinois at Urbana-Champaign; KEK	Measurement of High-Mass Dimuon Production at the 50-GeV Proton Synchrotron	Deferred			Primaly
P05	T. Nagae	KEK	Spectroscopic Study of Ξ-Hypernucleus, $^{12}{}_{\Xi}$Be, via the ^{12}C(K^-, K^+) Reaction	Stage 2	Day1	1	K1.8
P06	J. Imazato	KEK	Measurement of T-violating Transverse Muon Polarization in $K^+ \rightarrow \pi^0 \mu^+ \nu$ Decays	Stage 1			K1.1BR
P07	K. Imai, K. Nakazawa, H. Tamura	Kyoto U., Gifu U., Tohoku U.	Systematic Study of Double Strangeness System with an Emulsion-counter Hybrid Method	Stage 2			K1.8
P08	A. Krutenkova	ITEP	Pion double charge exchange on oxygen at J-PARC	Stage 1			K1.8
P10	A. Sakaguchi, T. Fukuda	Osaka U	Production of Neutron-Rich Lambda-Hypernuclei with the Double Charge-Exchange Reaction (Revised from Initial P10)	Stage 2			K1.8
P11	K. Nishikawa	KEK	Tokai-to-Kamioka (T2K) Long Baseline Neutrino Oscillation Experimental Proposal	Stage 2			neutrino
P13	T. Tamura	Tohoku U.	Gamma-ray spectroscopy of light hypernuclei	Stage 2	Day1	2	K1.8
P14	T. Yamanaka	Osaka University	Proposal for $K_L \rightarrow \pi^0 \nu\nu$-bar Experiment at J-PARC	Stage 2			K0
P15	M. Iwasaki, T. Nagae	RIKEN, KEK	A Search for deeply-bound kaonic nuclear states by in-flight 3He(K-, n) reaction	Stage 2	Day1		K1.8BR
P16	S. Yokkaichi	RIKEN	Electron pair spectrometer at the J-PARC 50-GeV PS to explore the chiral symmetry in QCD	Stage 1			High pt
P17	R. Hayano, H. Outa	U. Tokyo, RIKEN	Precision spectroscopy of Kaonic ^{3}He 3d->2p X-rays	Stage 2	Day1		K1.8BR
P18	H. Bhang, H. Outa, H. Park	SNU, RIKEN, KRISS	Coincidence Measurement of the Weak Decay of $^{12}{}_{\Lambda}$C and the three-body weak interaction process	Stage 1			K1.8
P19	M. Naruki	RIKEN	High-resolution Search for Θ^+ Pentaquark in $\pi^- p \rightarrow K^- X$ Reactions	Stage 2	Day1		K1.8
P21	Y. Kuno	Osaka U	An Experimental Search for μ - e Conversion at a Sensitivity of 10^{-16} with a Slow-Extracted Bunched Beam	Deferred			New beamline
P22	S. Ajimura, A. Sakaguchi	Osaka U	Exclusive Study on the Lambda-N Weak Interaction in A=4 Lambda-Hypernuclei (Revised from Initial P10)	Stage 1			K1.8
P23	A. D. Krisch	U. Michigan	Analyzing power An and Ann in 30-50GeV very-high-Pt2 proton-proton elastic scattering	Deferred			Primaly
P24	Y. Goto, H. Sato	RIKEN, KEK	Polarized proton acceleration at J-PARC	No decision			-

http://j-parc.jp/NuclPart/PACmeeting_0801_e.html

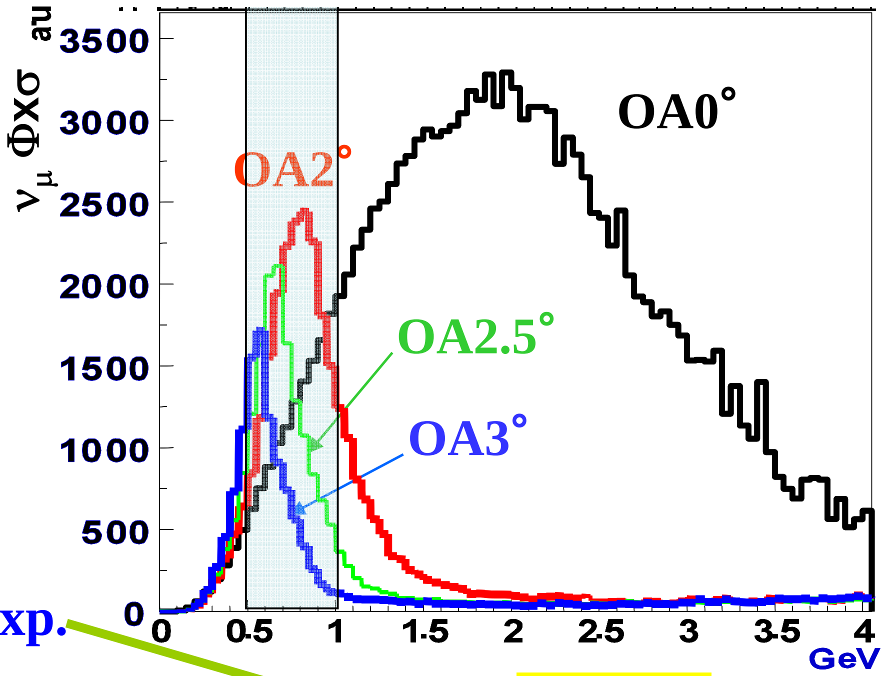
Summary of

Experiments at the J-PARC 50-GeV PS

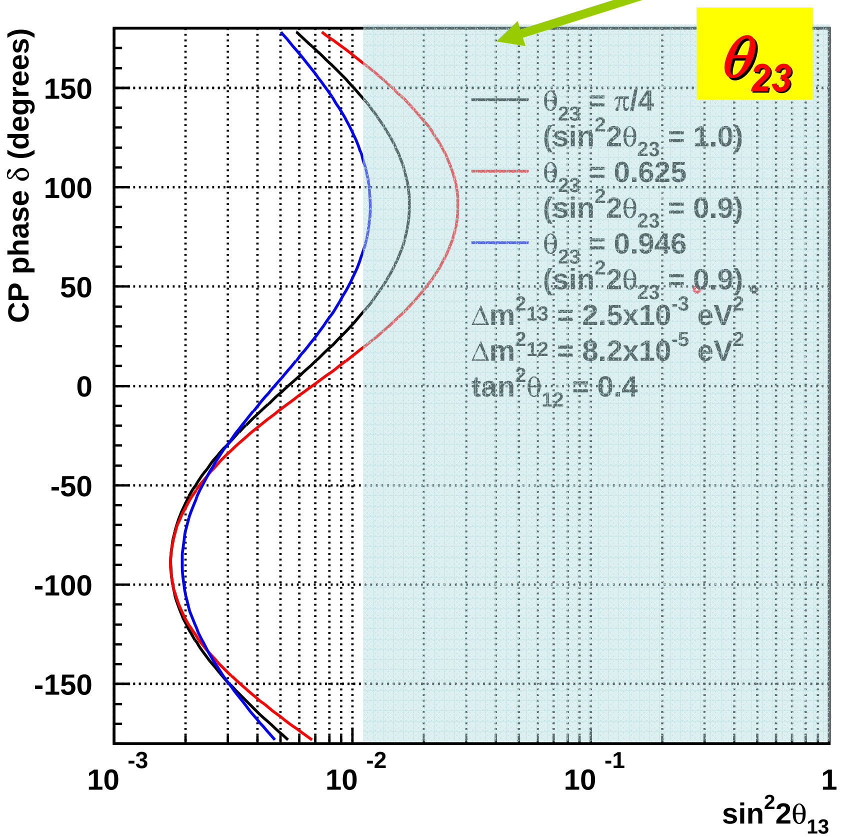
- ✓ Strangeness Nuclear Physics
  - Spectroscopic Studies of S=-2 hypernuclei (E03,E05,E07)
  - Spectroscopic Studies of S=-1 hypernuclei (E10,E13,E18,E22)
  - Spectroscopic Studies of Kaonic Nuclei (E15,E17)
- ✓ Hadron Physics
  - Spectroscopy of Exotic Hadrons (E19)
  - Chiral Restoration of Mesons in Nuclear Medium (E16)
  - Hadron Structure by DY process (P04,P23,P24)
- ✓ Kaon Rare Decay Physics
  - $K^0 \rightarrow \pi^0 \bar{\nu}\nu$: CP violating process (E14)
  - Transverse μ-pol. in $K^+ \rightarrow \pi^0 \mu^+ \nu$: T violating process (E06)
- ✓ Lepton Flavor Violation
  - LFV $\mu^- \rightarrow e^-$ conversion process (P21)
- ✓ Neutrino Physics
  - T2K Exp.: long baseline $\nu_\mu \rightarrow \nu_e$ oscillation (E11)

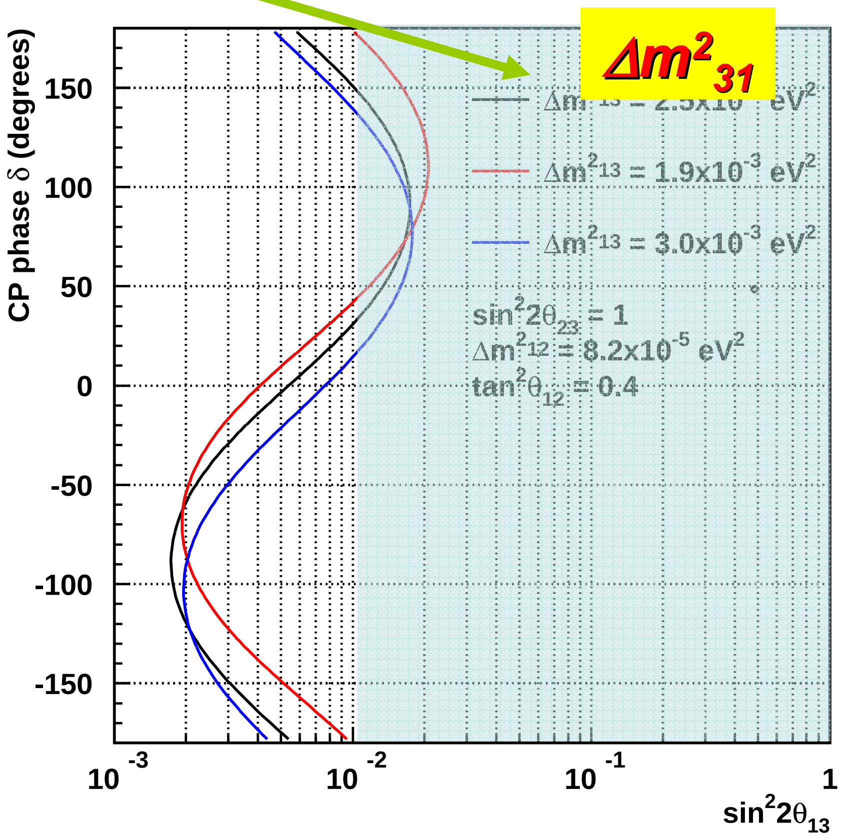
June, 2008


Kamioka
295 km
J-PARC
Tokai
KEK
T2K
1st beam in 2009

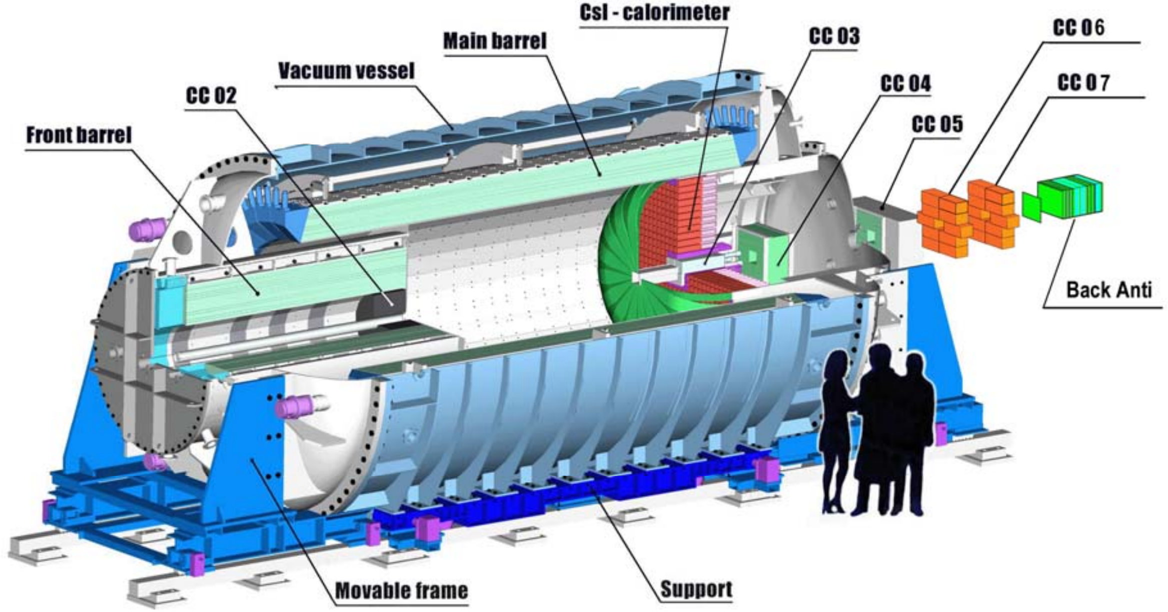

νμ Φxσ au
3500
3000
2500
2000
1500
1000
500
0
OA0°
OA2°
OA2.5°
OA3°
0
0.5
1
1.5
2
2.5
3
3.5
4
GeV

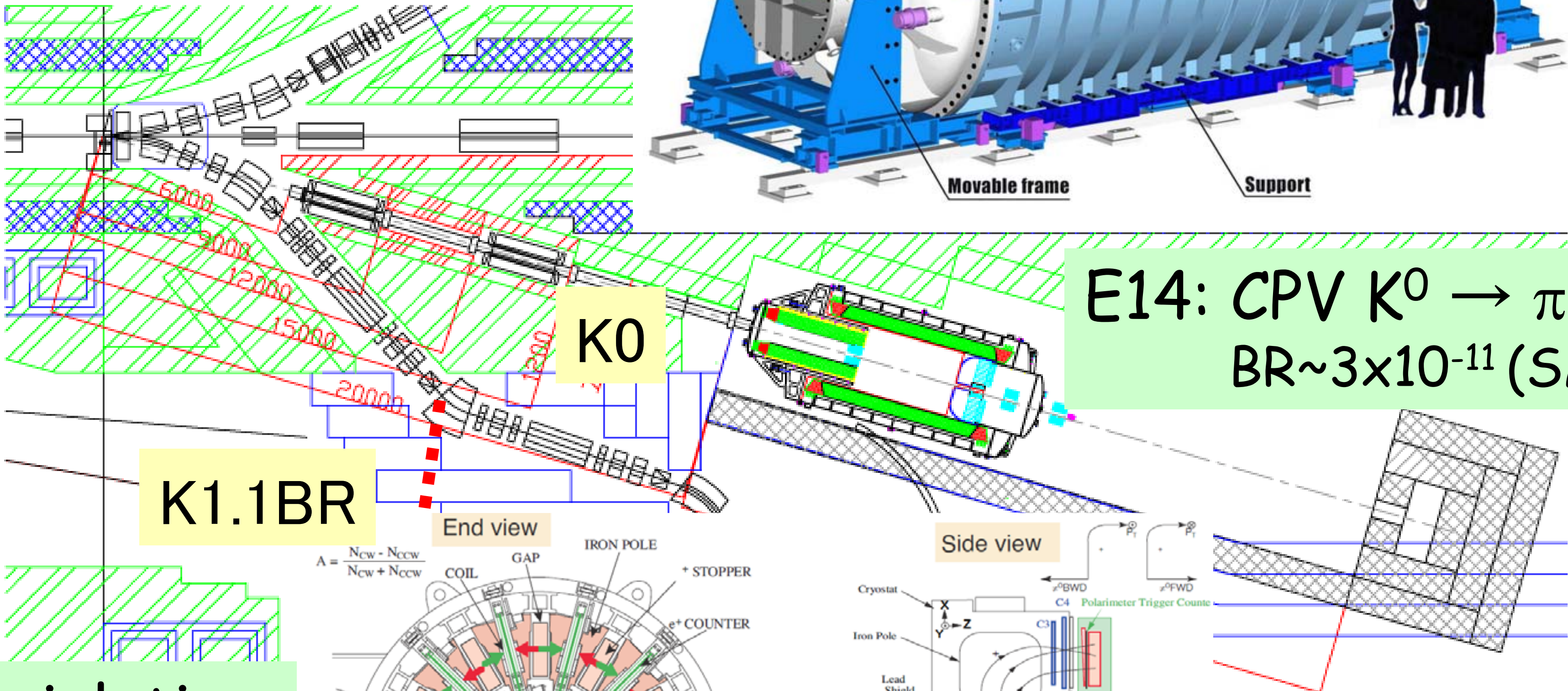
Reactor Exp.


θ23
CP phase δ (degrees)
150
100
50
0
-50
-100
-150
θ23 = π/4
(sin²2θ23 = 1.0)
θ23 = 0.625
(sin²2θ23 = 0.9)
θ23 = 0.946
(sin²2θ23 = 0.9)
Δm²13 = 2.5x10⁻³ eV²
Δm²12 = 8.2x10⁻⁵ eV²
tan²θ12 = 0.4
10⁻³
10⁻²
10⁻¹
1
sin²2θ13


Δm²31
CP phase δ (degrees)
150
100
50
0
-50
-100
-150
Δm²13 = 1.9x10⁻³ eV²
Δm²13 = 3.0x10⁻³ eV²
sin²2θ23 = 1
Δm²12 = 8.2x10⁻⁵ eV²
tan²θ12 = 0.4
10⁻³
10⁻²
10⁻¹
1
sin²2θ13

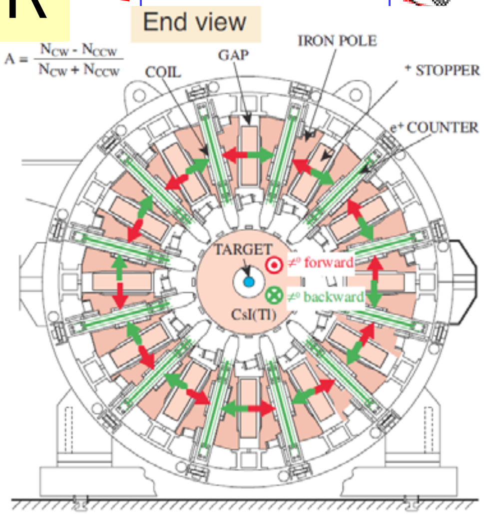
Search for Physics Beyond SM in Kaon Decays

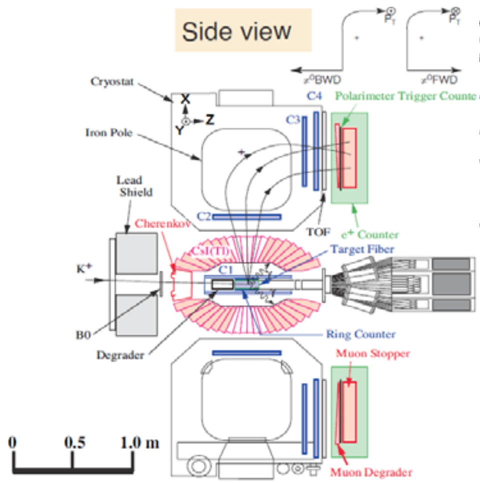




E14: CPV $K^0 \to \pi^0 \bar{\nu}\nu$

BR~3×10^{-11} (SM)





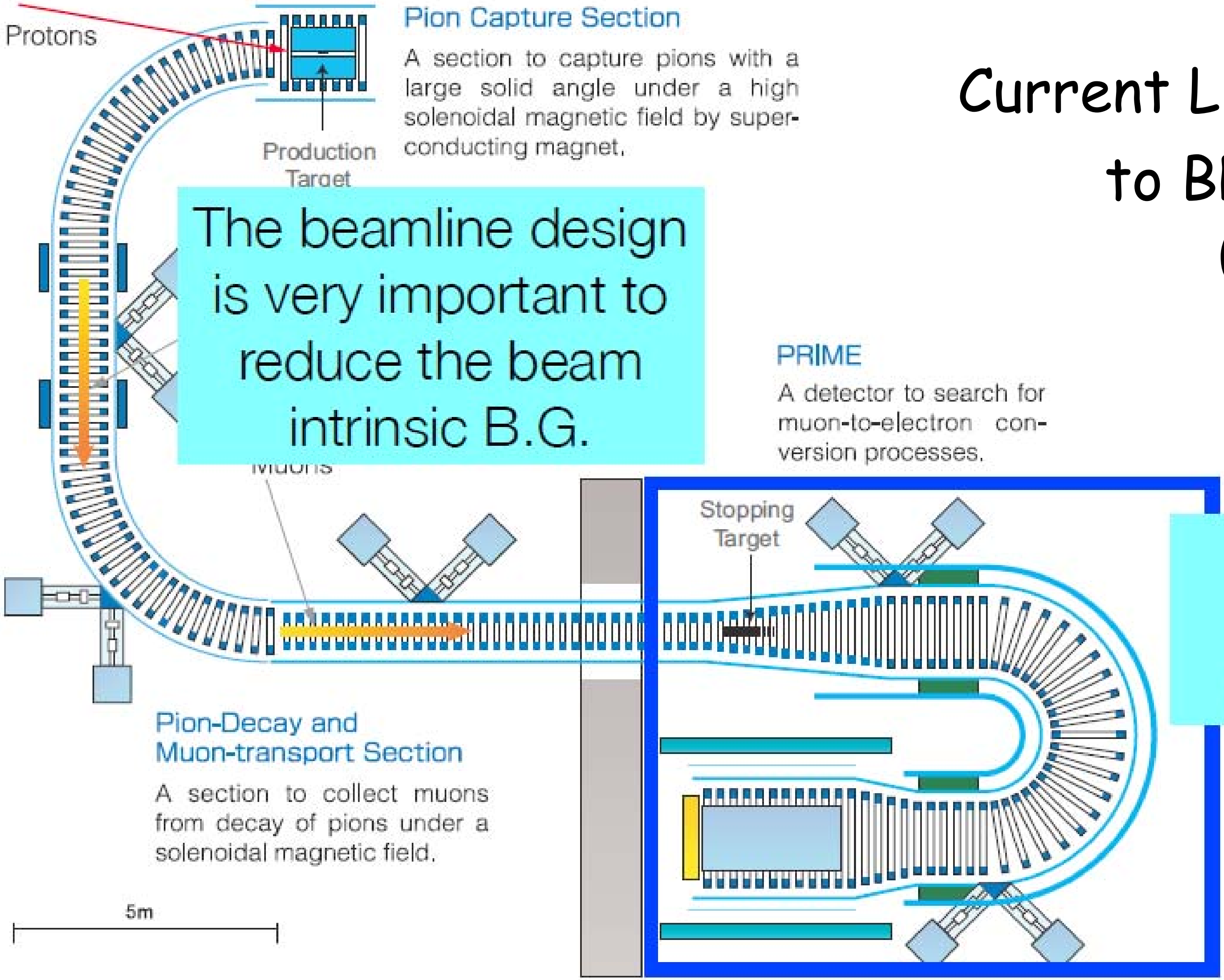
E06: T-violation in $K^+ \to \pi^0\mu^+ n$

(Transverse μ Pol. to ~10^{-4})

Experimental Search for Flavor Violating μ^--e^- conversion

P21: Y. Kuno et al.

Overview of the New Experiment : COMET



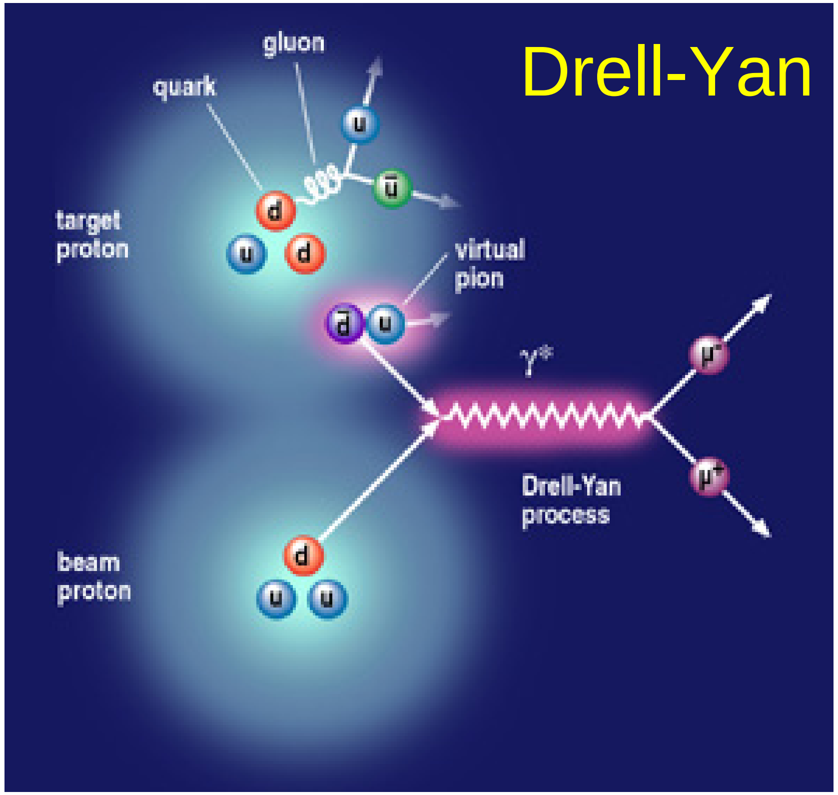
The beamline design is very important to reduce the beam intrinsic B.G.

Current Limit: BR~10^{-12} to BR~10^{-16} (m_ν: BR~10^{-50})

ID signals
B.G. reduction
hit rate reduction

Physics with High-Mass Dimuons at J-PARC

KEK S. Sawada



P04: J.C. Peng, S. Sawada

Drell-Yan (at 50 GeV):

- $\bar{d}/\bar{u}$ flavor asymmetry at large x
- Antiquark distributions in nuclei
- Quark energy loss in nuclei

J/Ψ Production (at 30 or 50 GeV):

- J/Ψ nuclear dependence
- $\bar{d}/\bar{u}$ via J/Ψ production

Spin physics with dimuons (mostly with polarized beam/target):

P24: Y. Goto、H. Sato

- Drell-Yan with polarized beam/target
  (Sea-quark polarizations, transversity, Sivers function)
- J/Ψ with polarized beam/target
  (Quark polarization, transversity, Sivers function)
- Unpolarized Drell-Yan decay angular distributions
  (Boer-Mulder's distribution function)

I larned...

Experimetal Topics related to J-PARC have been reported in the past SPIN2008:

Y. Goto introduced in 2006,

“Spin physics of the J-PARC dimuon experiment”

→ *P24*

N. Saito introduced

“J-PARC project: current status and future prospects”

So, this time:

Strangeness Nuclear Physics at J-PARC

Questions in Strangeness Nuclear Physics:

Q: Can We Understand the "*Nuclear Force*" within $SU_F(3)$?

Particularly,

Can We Reveal the *Short Range Part* in the BB interaction?

Do We Need *Quark DoF* ?

Q: Can We Understand the "*Nuclear Matter*" further more?

Particularly,

What is going on in *Dense Nuclear Matter* ?

Is Neutron Star *Hyperon Star*?

Is *Quark Star existing*? *Strange Quark Matter*?

Q: How change the *Hadron Property in Media* ?

related to *(partial) Restoration of Chiral Symmetry*,
may reveal the mechanism of quark condensations.

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Particularly,

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What is going on in *Dense Nuclear Matter* ?

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Q: How change the *Hadron Property in Media* ?

related to *(partial) Restoration of Chiral Symmetry*,
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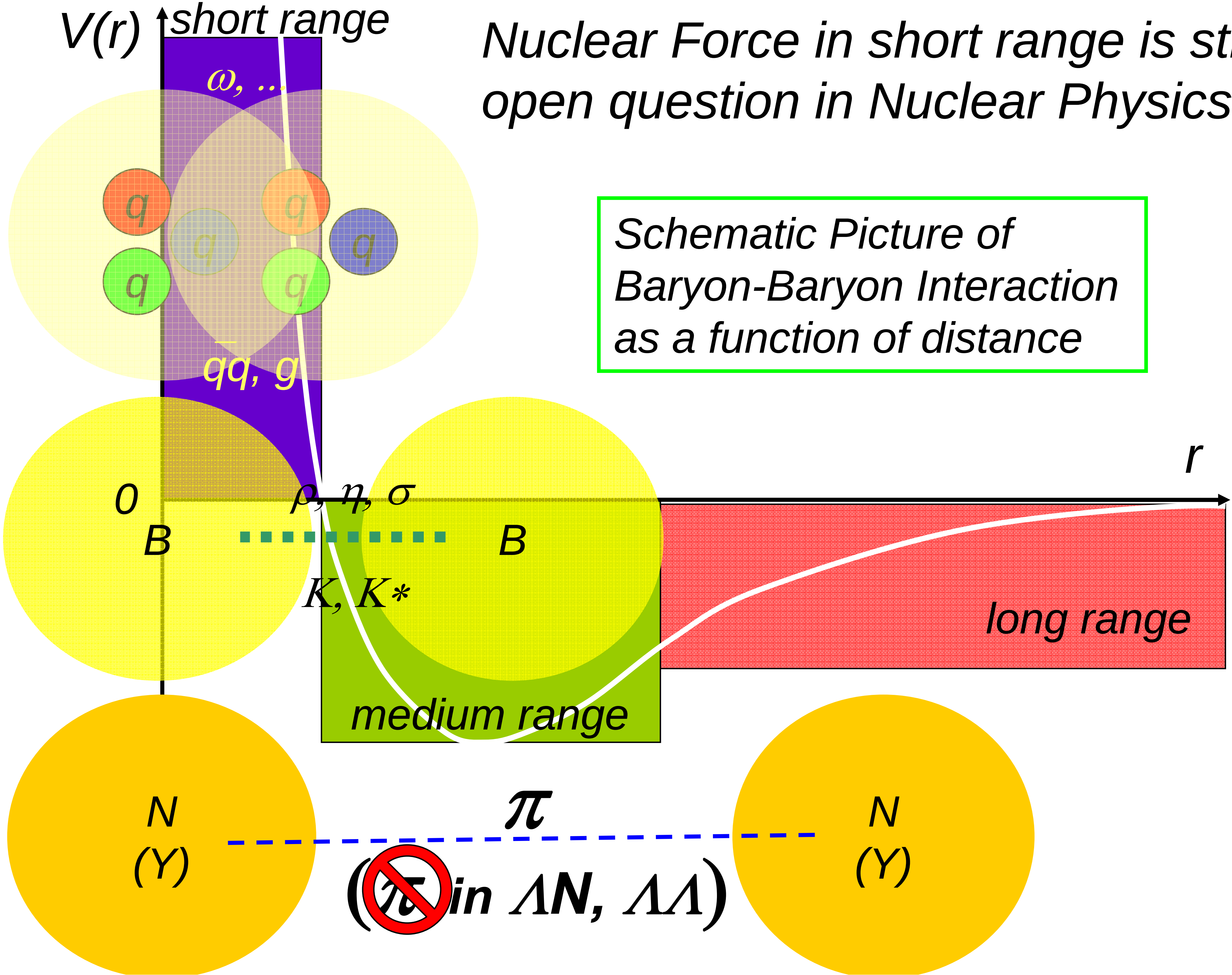
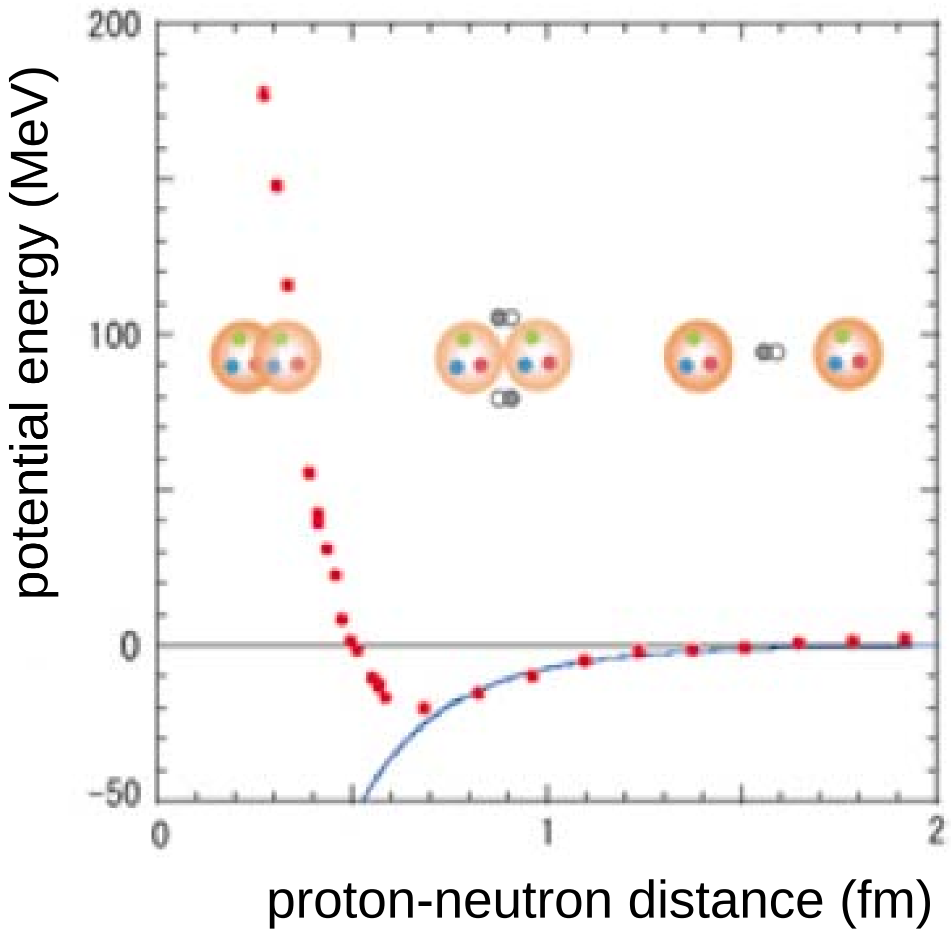
Nuclear Force in short range is still open question in Nuclear Physics.

Schematic Picture of Baryon-Baryon Interaction as a function of distance

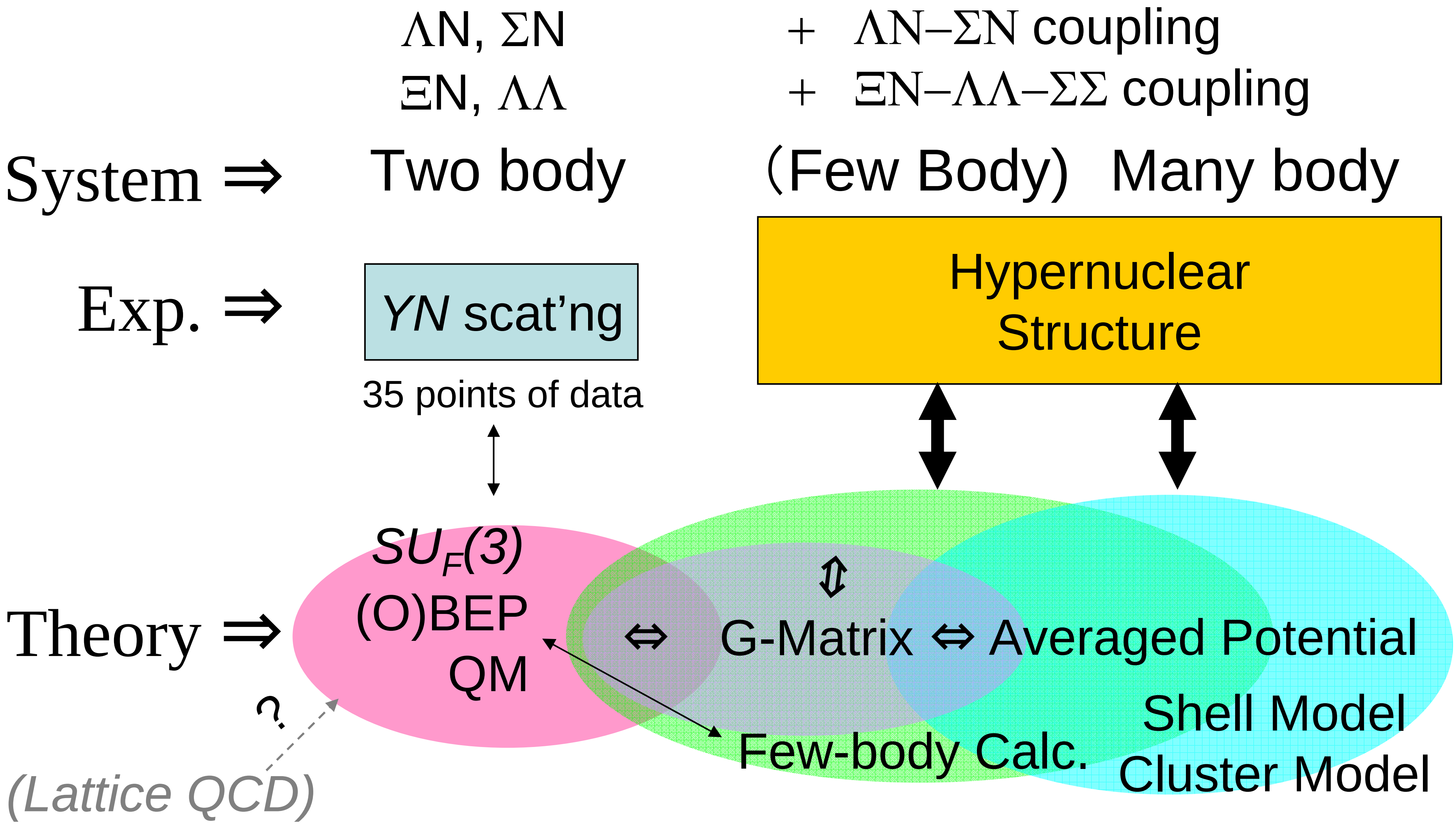


Lattice QCD reproduced Yukawa's Nuclear Force and demonstrated repulsive core in the NN potential!



N. Ishii, S. Aoki and T. Hatsuda
Physical Review Letters vol. 99、022001(2007)

Precision Hypernuclear Spectroscopic Data
reveal *the Baryon-Baryon Interactions*
in collaboration with Precision Theoretical Calculations



BB Interaction through Hypernuclear Spectroscopy

- *In Λ hypernuclear system, the frameworks work very well, demonstrating that:*
  - *Single-Particle Structure: $B_\Lambda \rightarrow U_\Lambda$ G-matrix concept: Good*
  - *Spin-Spin, Spin-Orbit splitting: ΛN spin-dependent force*

→ BB Potential Models, reproducing Λ Single-Particle Potential

Precise Measurements make the Model more precise.

	$^1S_0$	$^3S_1$	$^1P_1$	$^3P_0$	$^3P_1$	$^3P_2$	D	U_Λ
ESC04a	–13.7	–20.5	0.6	0.2	0.5	–4.5	–1.0	–38.5
ESC04b	–13.3	–22.6	0.5	–0.0	0.6	–4.3	–1.1	–40.2
ESC04c	–13.9	–28.5	2.9	0.0	1.3	–6.5	–1.3	–46.0
ESC04d	–13.6	–26.6	3.2	–0.2	0.9	–6.4	–1.4	–44.1
NSC97e	–12.7	–25.5	2.1	0.5	3.2	–1.3	–1.2	–34.8
NSC97f	–14.3	–22.4	2.4	0.5	4.0	–0.7	–1.2	–31.8
fss2	-4.8	-28.4*	2.1#	-0.4		-5.7		-48.2

*$^3S_1$+$^3D_1$ # $^1P_1$+$^3P_1$

"**OBEP based**"
Th. A. Rijken and Y. Yamamoto, Phys.Rev.C73: 044008,2006

"**QM based**"
Y. Fujiwara et al., Prog.Part.Nucl.Phys. 58:439, 2007

k_f=1.35 fm^{-1}

BB Potential Models and Σ Single-Particle Potential in Nucl. Matt.

- U_Σ's are to be repulsive. (E438 exp.)

OBEP based: to be improved.

QM: Strong repulsion due to the Quark Pauli Exclusion Effect in I=3/2, S=1

	T	$^1S_0$	$^3S_1$	$^1P_1$	$^3P_0$	$^3P_1$	$^3P_2$	D	U_Σ
ESC04a	1/2	11.6	−26.9	2.4	2.7	−6.4	−2.0	−0.8	
	3/2	−11.3	2.6	−6.8	−2.3	5.9	−5.1	−0.2	−36.5
ESC04b	1/2	9.6	−25.3	1.8	1.6	−5.4	−2.1	−0.7	
	3/2	−9.6	9.9	−5.5	−1.9	5.4	−4.6	−0.2	−27.1
ESC04c	1/2	6.4	−20.6	2.4	2.9	−6.7	−1.6	−0.9	
	3/2	−10.7	6.9	−8.8	−2.6	6.0	−5.8	−0.2	−33.2
ESC04d	1/2	6.5	−21.0	2.6	2.4	−6.7	−1.7	−0.9	
	3/2	−10.1	14.0	−8.5	−2.6	5.9	−5.7	−0.2	−26.0
NSC97f	1/2	14.9	−8.3	2.1	2.5	−4.6	0.5	−0.5	
	3/2	−12.4	−4.1	−4.1	−2.1	6.0	−2.8	−0.1	−12.9
fss2	1/2	6.7	-23.9*	-6.5#	2.9		-1.6		
	3/2	-9.2	41.2*	3.3#	-2.2		-2.5		7.5

*$^3S_1+^3D_1$ # $^1P_1+^3P_1$

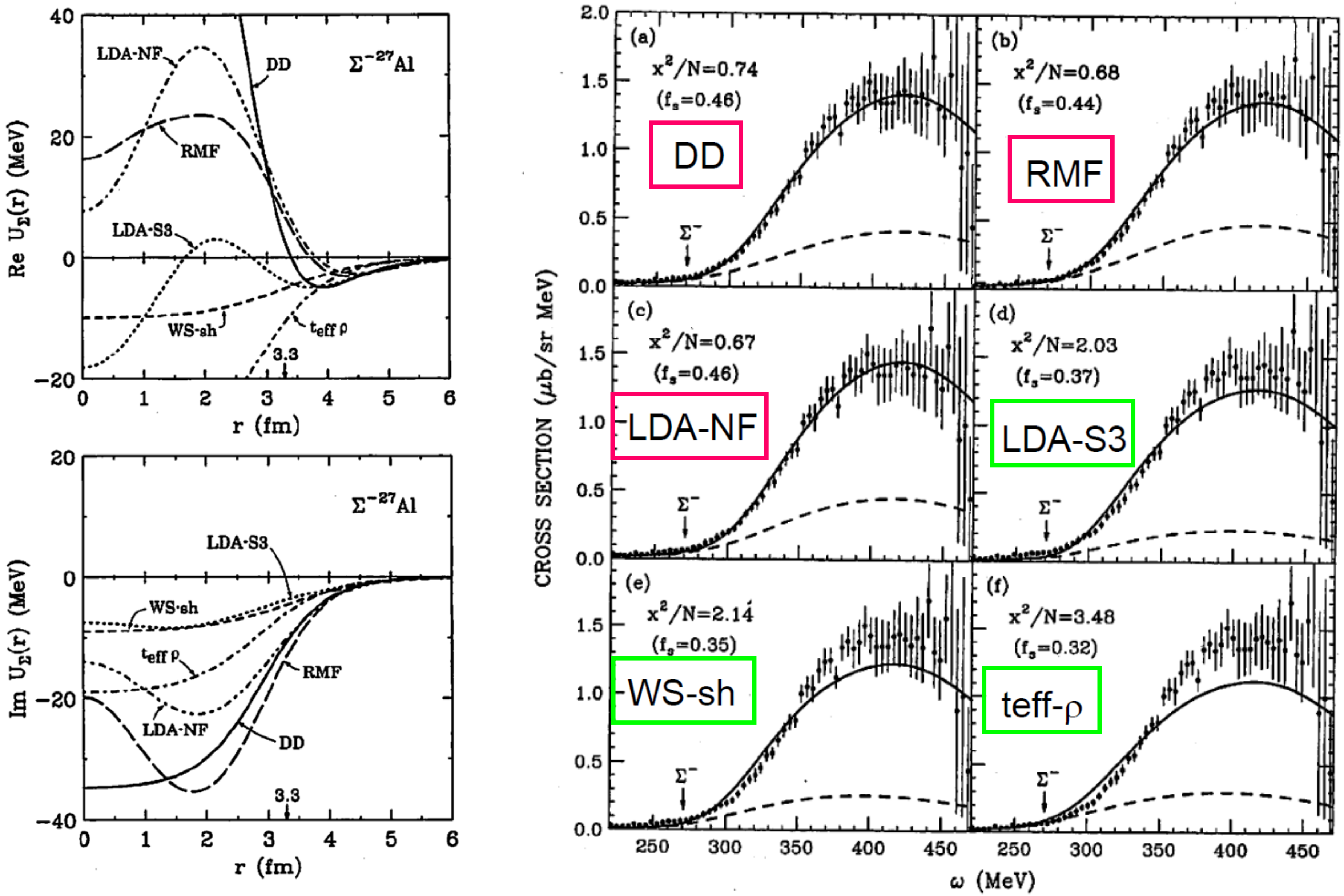
"**OBEP based**"
Th. A. Rijken and Y. Yamamoto, Phys.Rev.C73: 044008,2006
k_f=1.0 fm^{-1}

"**QM based**"
Y. Fujiwara et al., Prog.Part.Nucl.Phys. 58:439, 2007
k_f=1.35 fm^{-1}

Demonstration of Repulsive U_Σ via the (π^-,K^+) reaction on Si

Exp. Data→ **P. K. Saha, Phys. Rev. C70, 044613(2004)**

Si **DWIA calculation→** T. Harada and Y. Hirabayashi, NPA759(2005)143

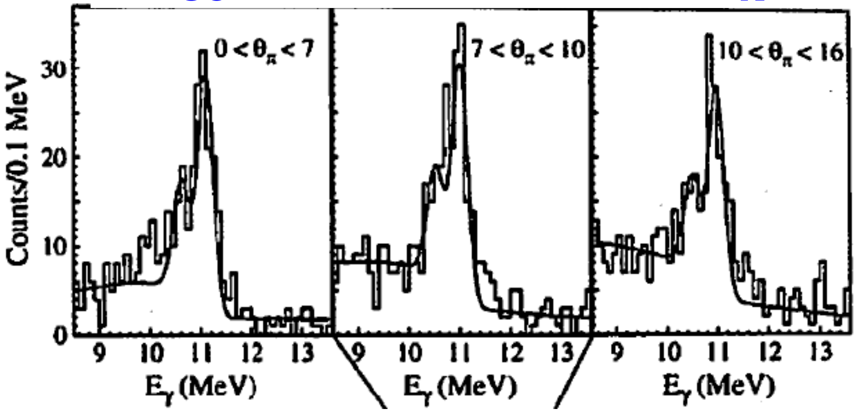


Do We Need Quark?

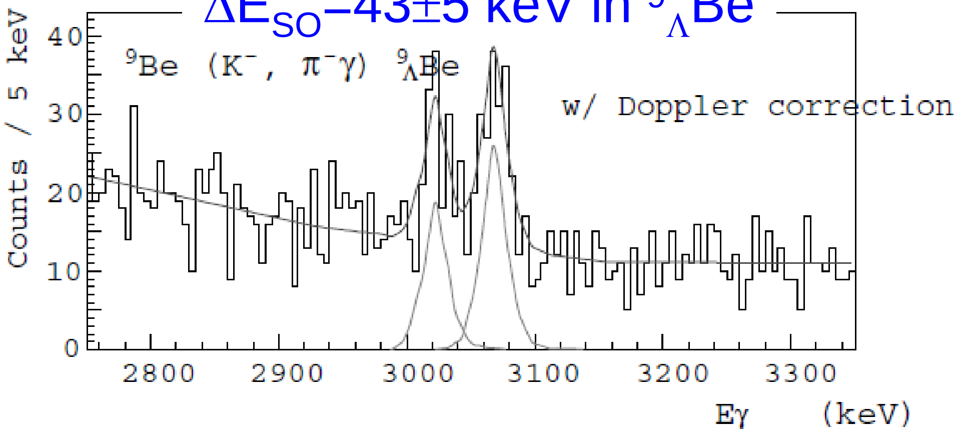
S. Ajimura et al, PRL86, 4255(2001)
T. Akikawa et al., PRL88, 082501(2002)

- Very Small SO splitting in Λ Hypernucei
- Large SO force in Σp Scattering: T. Kadowaki et al. Eur.P.J.A15:295(2002)

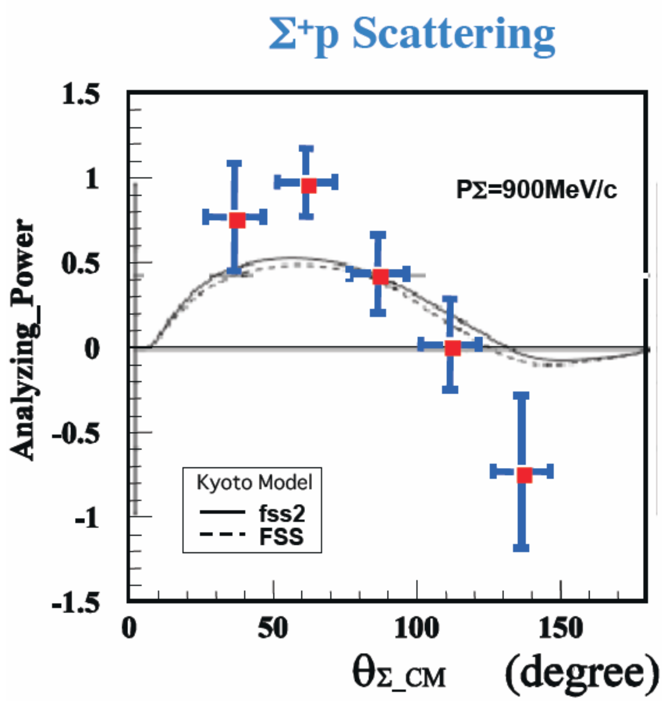
ΔE_{SO}=136±54±36 keV in $^{13}{}_{\Lambda}$C



ΔE_{SO}=43±5 keV in $^{9}{}_{\Lambda}$Be



→ Agree w/ Naive Quark Model



- Strong Repulsive Σ-Nucleus Pot.: P.K.Saha et al.PRC70, 044613(2004)

→ Quark Pauli Exclusion Effect

Do We Need Quark?

Let's Exam. including S=-2 Sector at J-PARC!

Very Little Experimental Information is Available for S=-2.

Ξ-Hypernuclear Spectroscopy
(E05)

U_Ξ and Partial Wave Contributions in Nuclear Matter

(MeV)

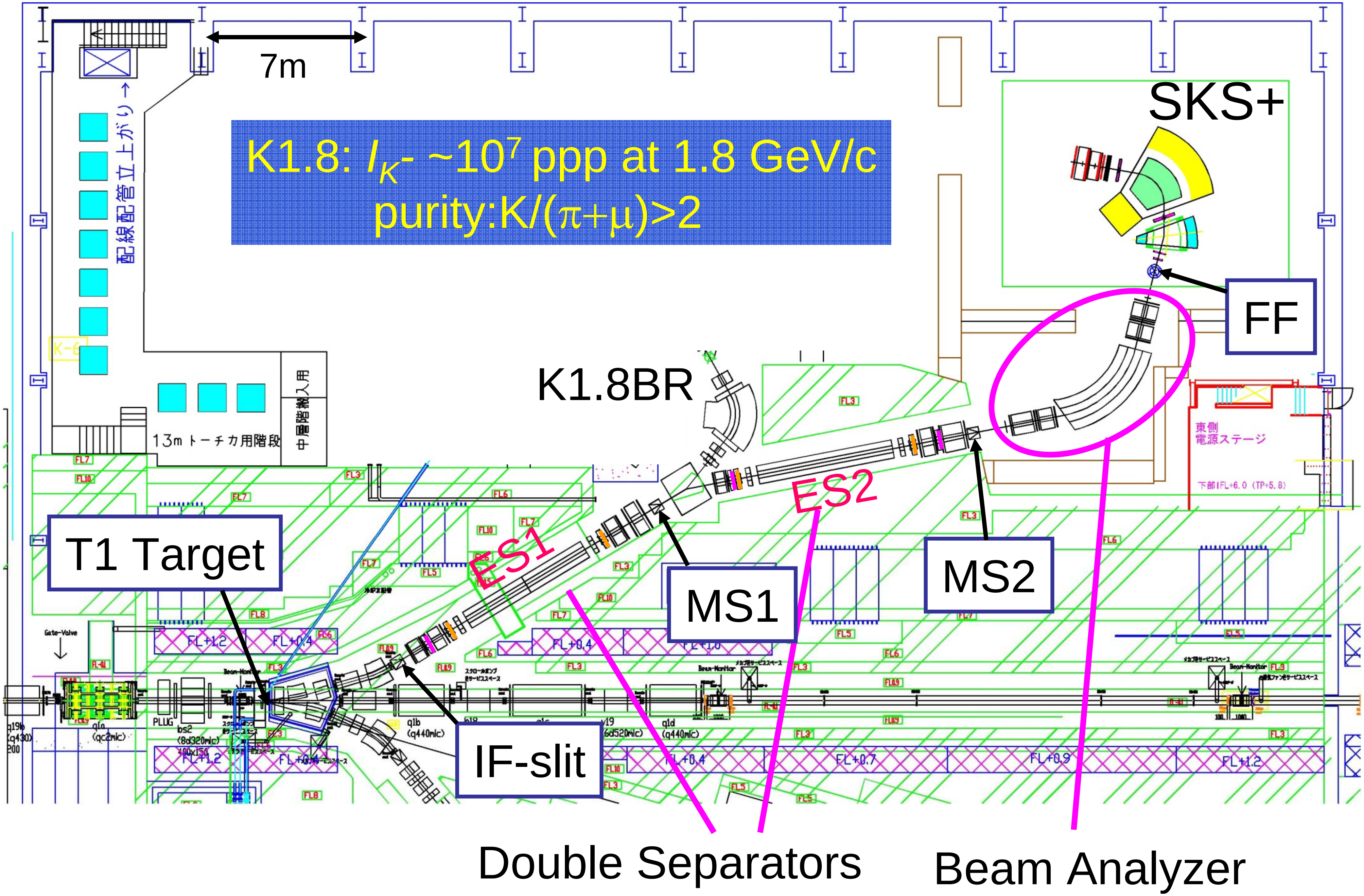
Model	T	$^1S_0$	$^3S_1$	$^1P_1$	$^3P_0$	$^3P_1$	$^3P_2$	U_Ξ	Γ_Ξ
NHC-D	0	–2.6	0.1	–2.1	–0.2	–0.7	–1.9		
	1	–3.2	–2.3	–3.0	–0.0	–3.1	–6.3	–25.2	0.9
Ehime	0	–0.9	–0.5	–1.0	0.3	–2.4	–0.7		
	1	–1.3	–8.6	–0.8	–0.4	–1.7	–4.2	–22.3	0.5
ESC04d*	0	6.3	–18.4	1.2	1.5	–1.3	–1.9		
	1	7.2	–1.7	–0.8	–0.5	–1.2	–2.8	–12.1	12.7

QM: fss2 → –5.3

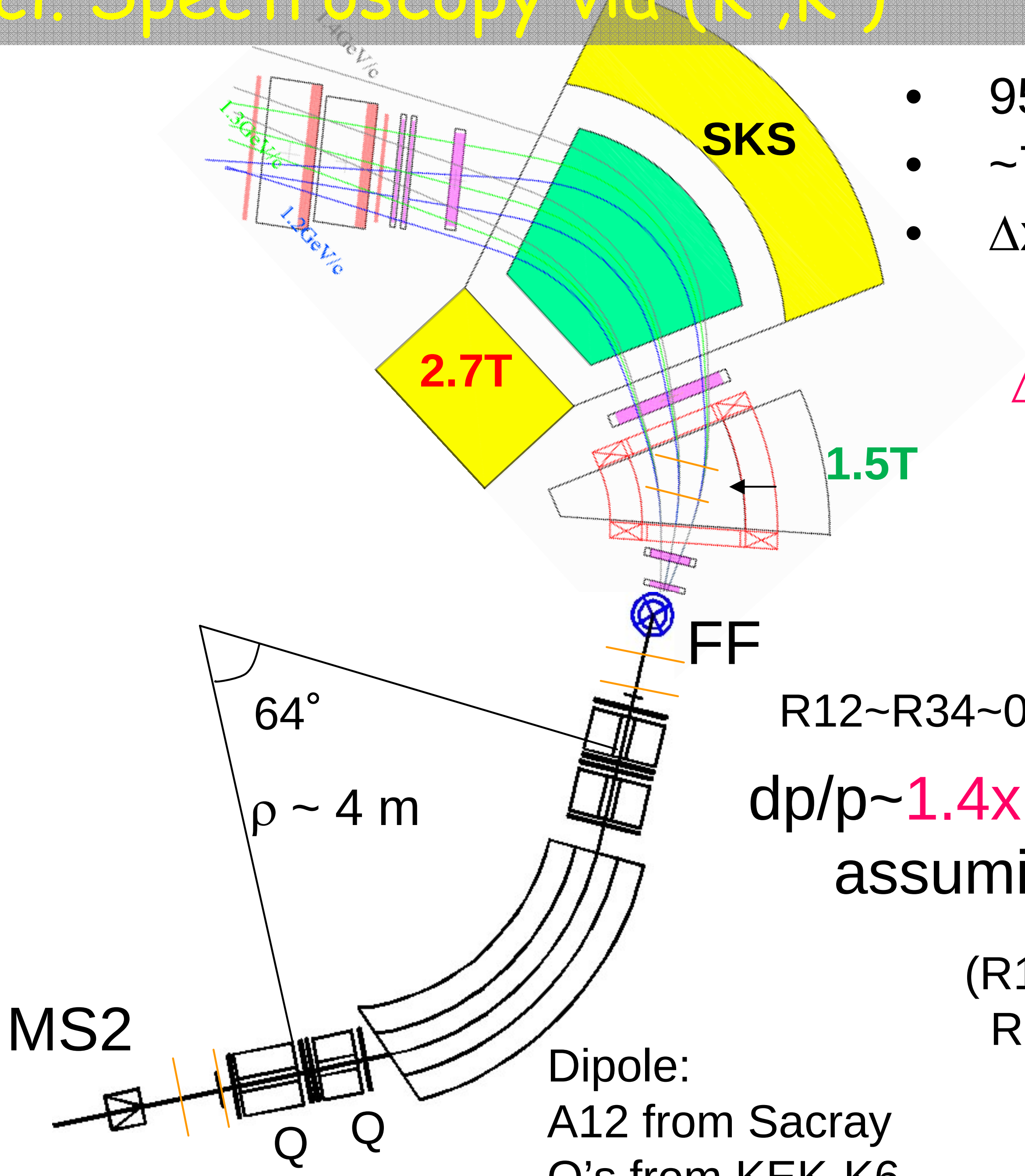
- ✓ OBE (NHC-D: M.M.Nagels et al., PRD12, 744(1975), Ehime:Nucl.Phys.A642:483(1998))
  odd-state attraction
  strong A-dependence of U_Ξ
- ✓ ESC04d*: Th. A. Rijken and Y. Yamamoto, PRC73,044008(2006)
  strong attraction of $^3S_1$(T=0)
- ✓ QM: Y. Fujiwara et al., NPA784,161(2007)
  strong Spin-Isospin dependence,
  S(I=1) repulsion (Quark-Pauli) → shallow U_Ξ

Separated Kaon Beam Line: K1.8

(Max. p=2 GeV/c, **Total Length:45.853 m**)



Beam Analyzer & SksPlus spectrometer System for Ξ-Hyp'nucl. Spectroscopy via (K^-,K^+)



- 95° total bend
- ~7m flight path
- Δx=0.3 mm (RMS)

Ω~30msr

Δp/p=0.12%

R12~R34~0@FF

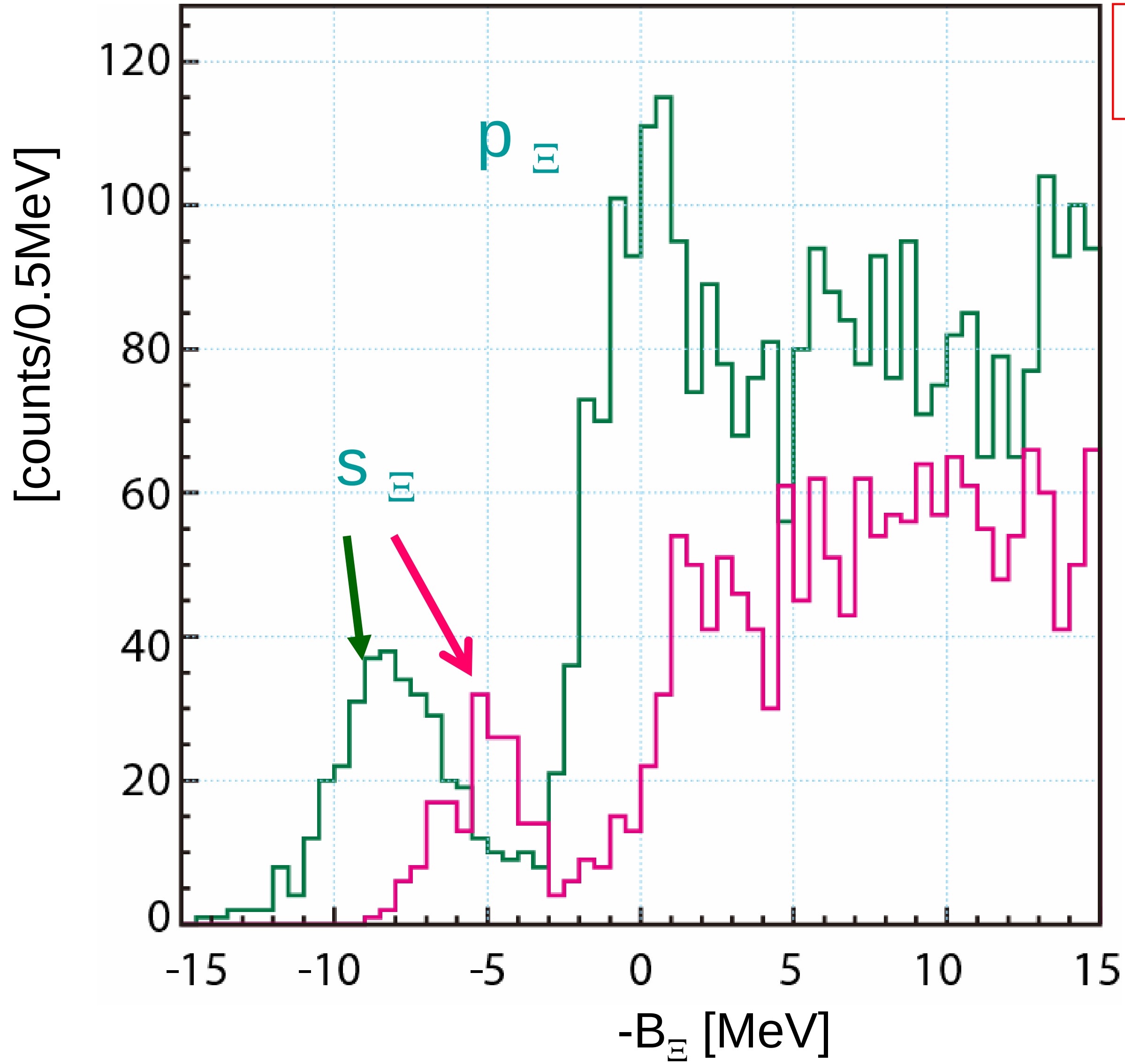
dp/p~1.4×10^{-4} (in σ)

assuming σ_x~200μm

(R11=-0.44, R12=0, R16=1.57 cm/%)

Dipole:
A12 from Sacray
Q's from KEK-K6

Expected $^{12}{}_{\Xi}$Be Spectrum



$\Delta E_{meas.}$ = 3 MeV_{FWHM}

V_{Ξ}= -20MeV

V_{Ξ}= -14MeV

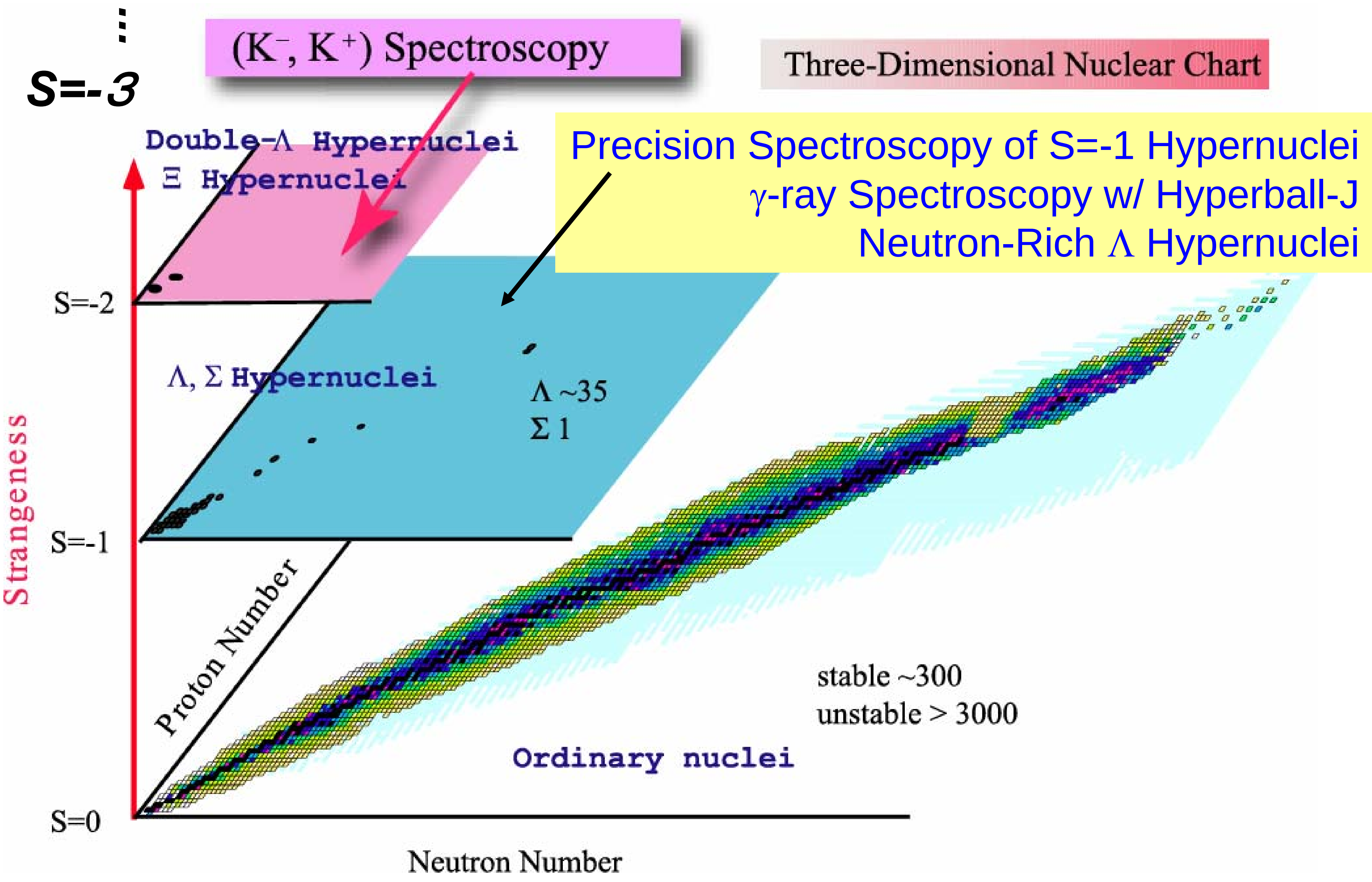
Extension of Nuclear World

S→∞

⋮

S=-*3*

Strangeness implanted in Nuclear Matter



Questions in Strangeness Nuclear Physics:

Q : Can We Understand the "*Nuclear Force*" within $SU_F(3)$?

Particularly,

Can We Reveal the *Short Range Part* in the BB interaction?

Do We Need *Quark DoF* ?

Q : Can We Understand the "*Nuclear Matter*" further more?

Particularly,

What is going on in *Dense Nuclear Matter* ?

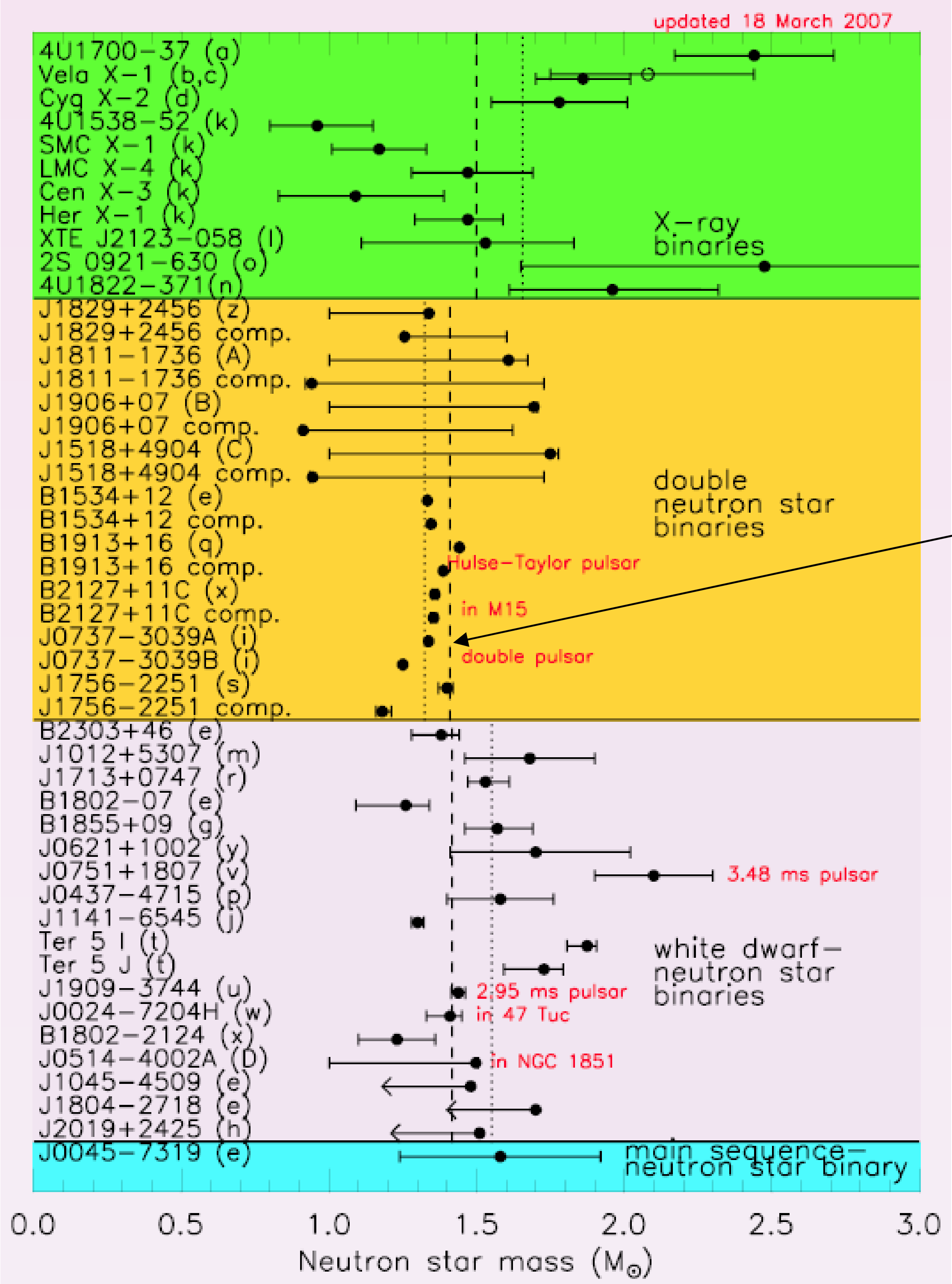
Is Neutron Star Hyperon Star?

→ How is Quark Star/Strange Quark Matter existing?

Q : How change the *Hadron Property in Media* ?

related to *(partial) Restoration of Chiral Symmetry*,

may reveal the mechanism of quark condensations.



Are Observed NS Masses No Heavier than 1.5xSolar Mass?

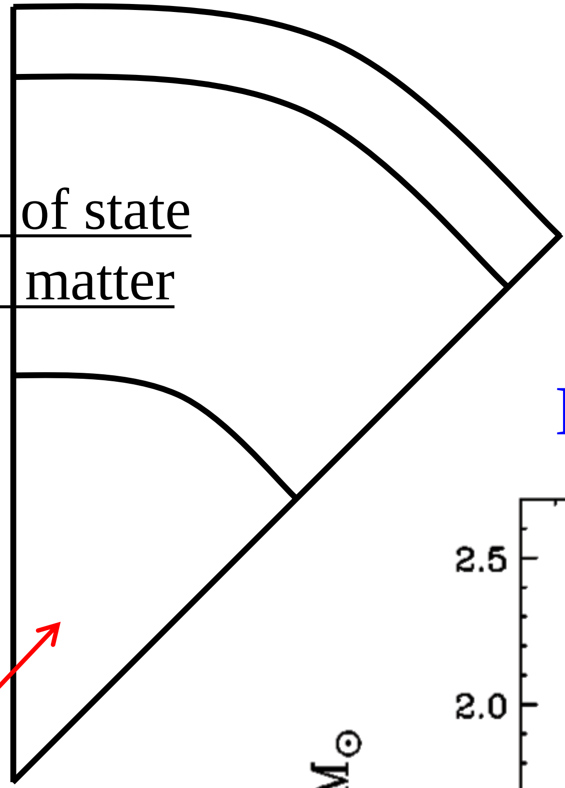
$M_{NS}<1.44M_\odot$

IF it is "Yes"...

The NS core is likely to contains
a fraction of Hyperons.

from W. Weise, plenary talk in INPC07, 4/jun/2007

Neutron star

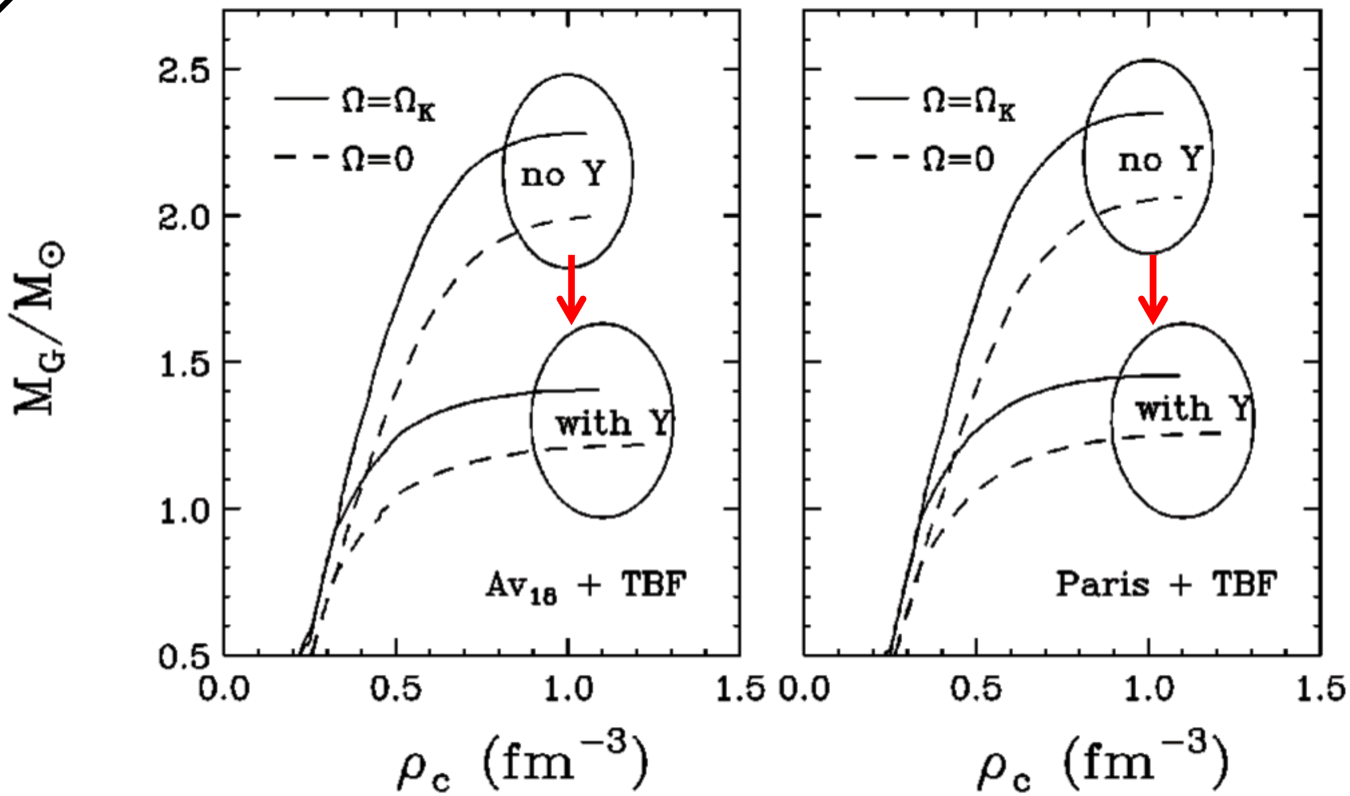


Equation of state for dense matter

Hyperon mixing in NS core makes the EoS soft.

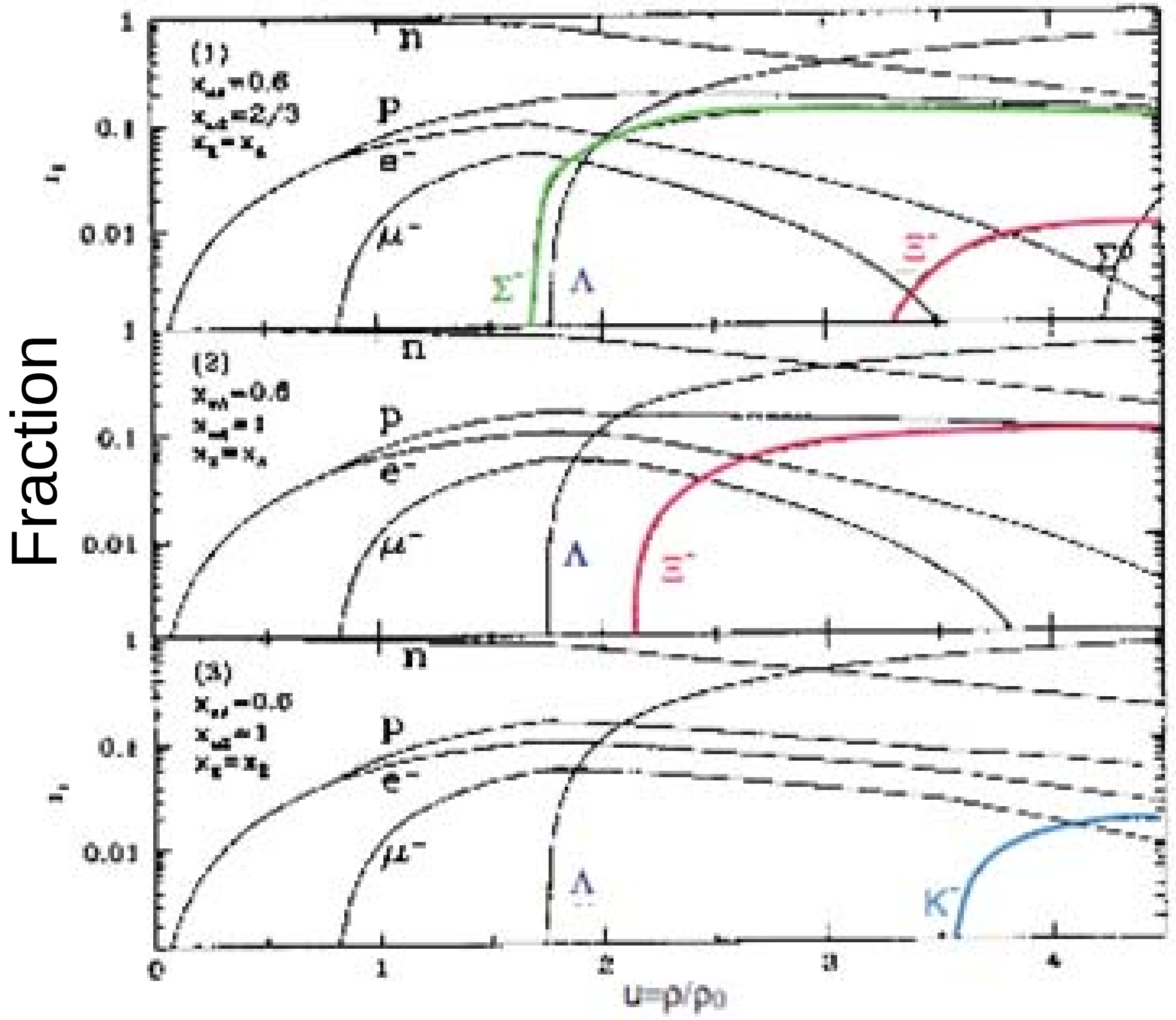
Max. Mass$<1.44M_{solar}$

M. Baldo et al. PRC61(2000) 055801



Ξ hypernuclear potential ?

- Λ, Σ⁻, Ξ⁻, K⁻ in Neutron Star Core ?
  - Chemical Potential: $\mu_B = m_B + \frac{k_F^2}{2m_B} + \boxed{U(k_F)}$



$U_\Sigma < 0$, $U_\Xi < 0$

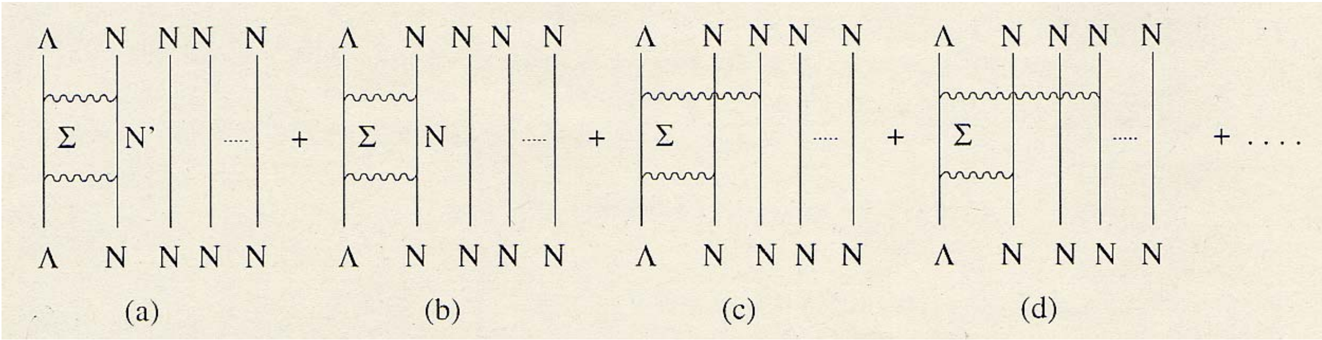
$U_\Sigma > 0$, $U_\Xi < 0$

$U_\Sigma > 0$, $U_\Xi > 0$

$\rightarrow U_{K^-}$

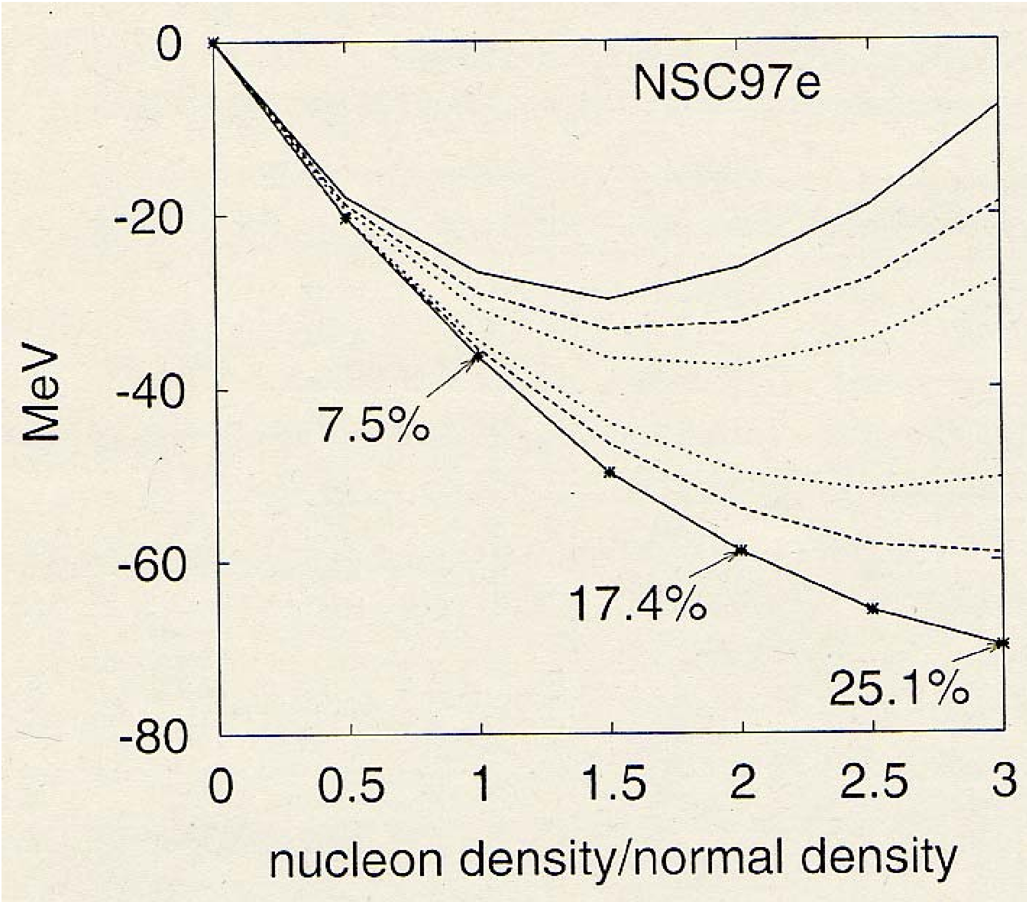
Role of the ΛN-ΣN coupling in Neutron Star Cores

S.Shinmura, K. S. Myint, T. Harada, and Y. Akaishi, J. Phys. G28(2002)L1



coherent Λ→Σ
w/o exciting N
(b)~(d)…
No effect in T=0

Single-particle Λ potential in neutron matter ($T=\infty$)



p=0%
p=10%
p=20%

without coherent
ΛN-ΣN coupling

p=20%
p=10%
p=0%

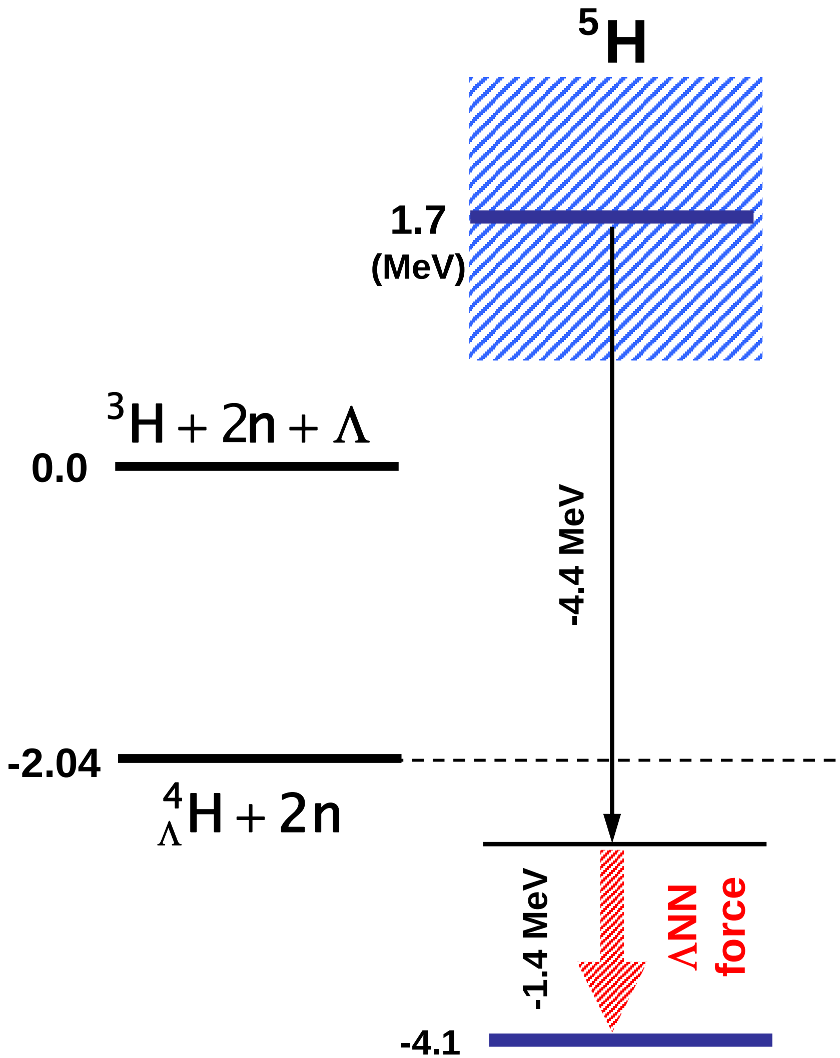
with coherent
ΛN-ΣN coupling

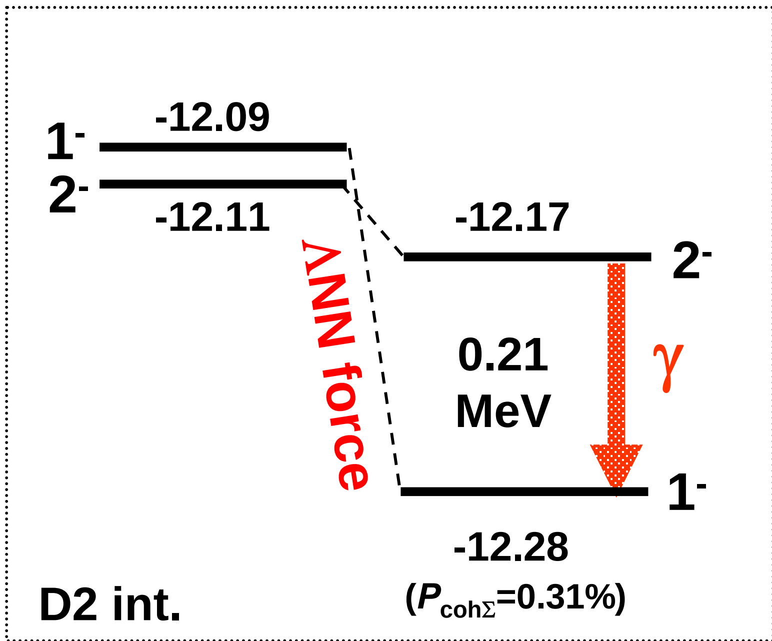
P_{Σ^0} increases with ρ_N

ΛΣ Coherent Coupling Effect

Y. Akaishi et al.

Superheavy hydrogen



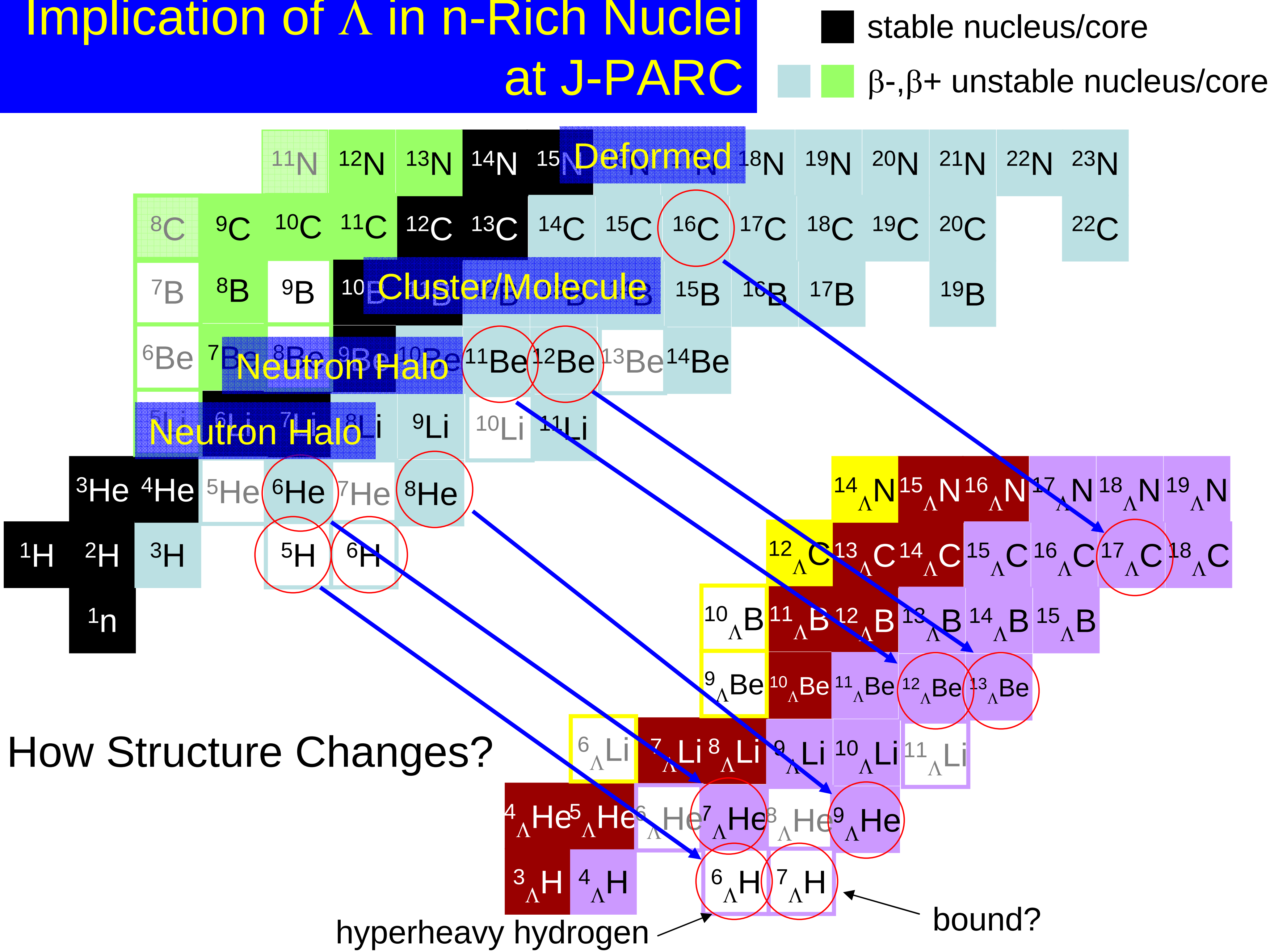


$^{10}_{\Lambda}$Li

^{6}Li (π^-, K$^+$) $^6_\Lambda$H → E10: A. Sakaguchi et al

“Hyperheavy hydrogen”

Implication of Λ in n-Rich Nuclei at J-PARC



How Structure Changes?

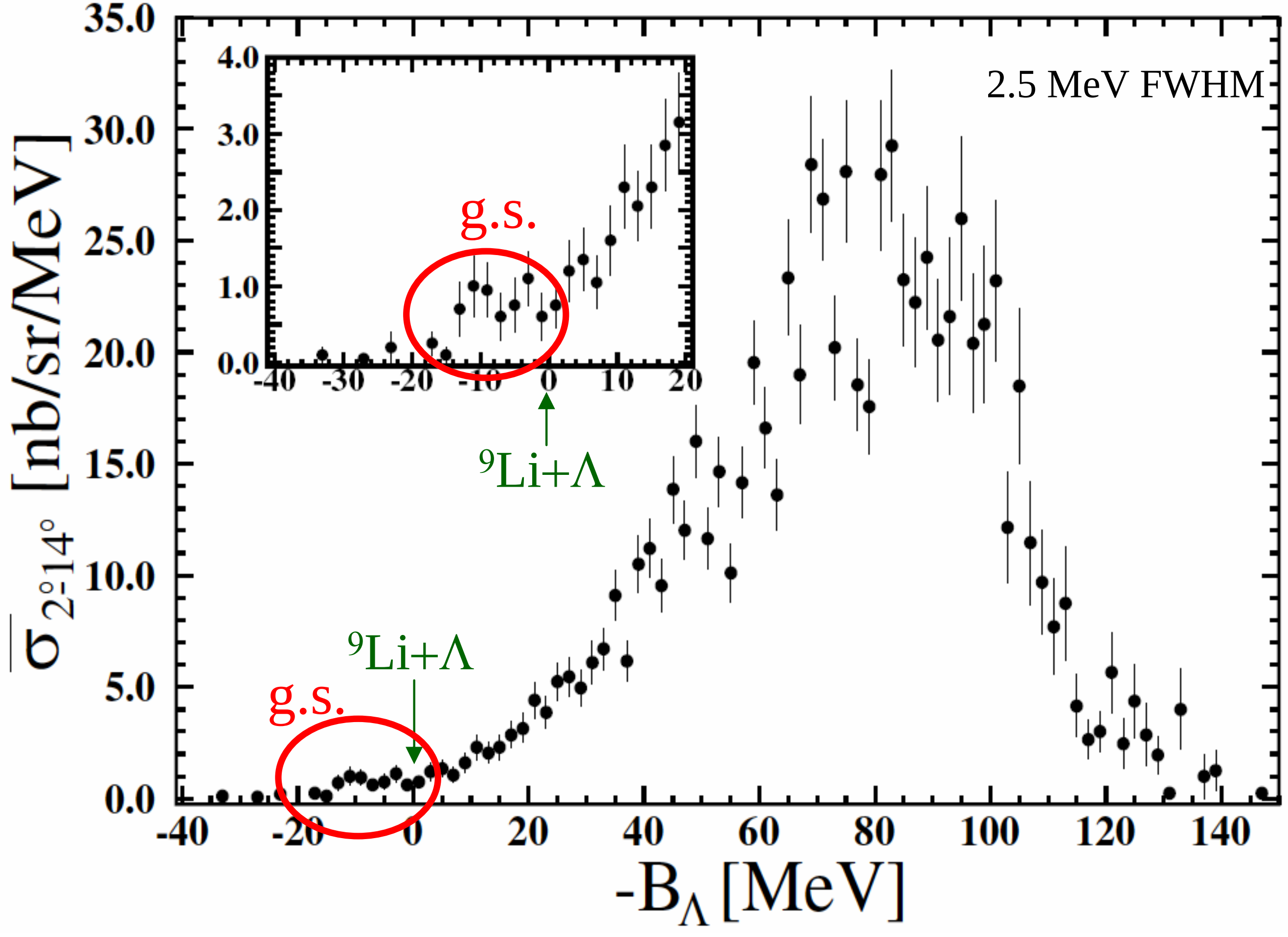
First Observation of n-rich $^{10}_{\Lambda}$Li via the (π^-,K^+) reaction at KEK-PS

$d\sigma/d\Omega$ = 11.3±1.9 nb/sr at 1.2 GeV/c

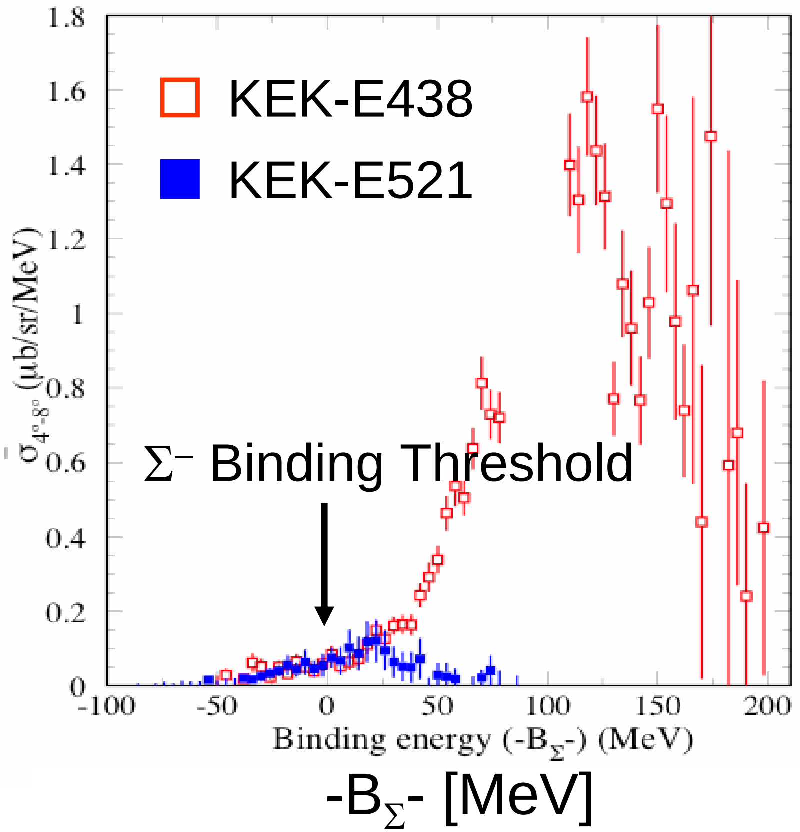
as small as ~1/1000 of (π^+,K^+)

→ the Λ state produces via Σ component through $\Lambda\Sigma$ coupling ?

KEK-PS-E521 P. K. Saha, et al., PRL94(2005)052502



consistent w/
Absorptive
Imaginary Σ-Nucl. Potential



Questions in Strangeness Nuclear Physics:

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Particularly,

What is going on in *Dense Nuclear Matter* ?

Is Neutron Star *Hyperon Star*?

Is *Quark Star existing*? *Strange Quark Matter*?

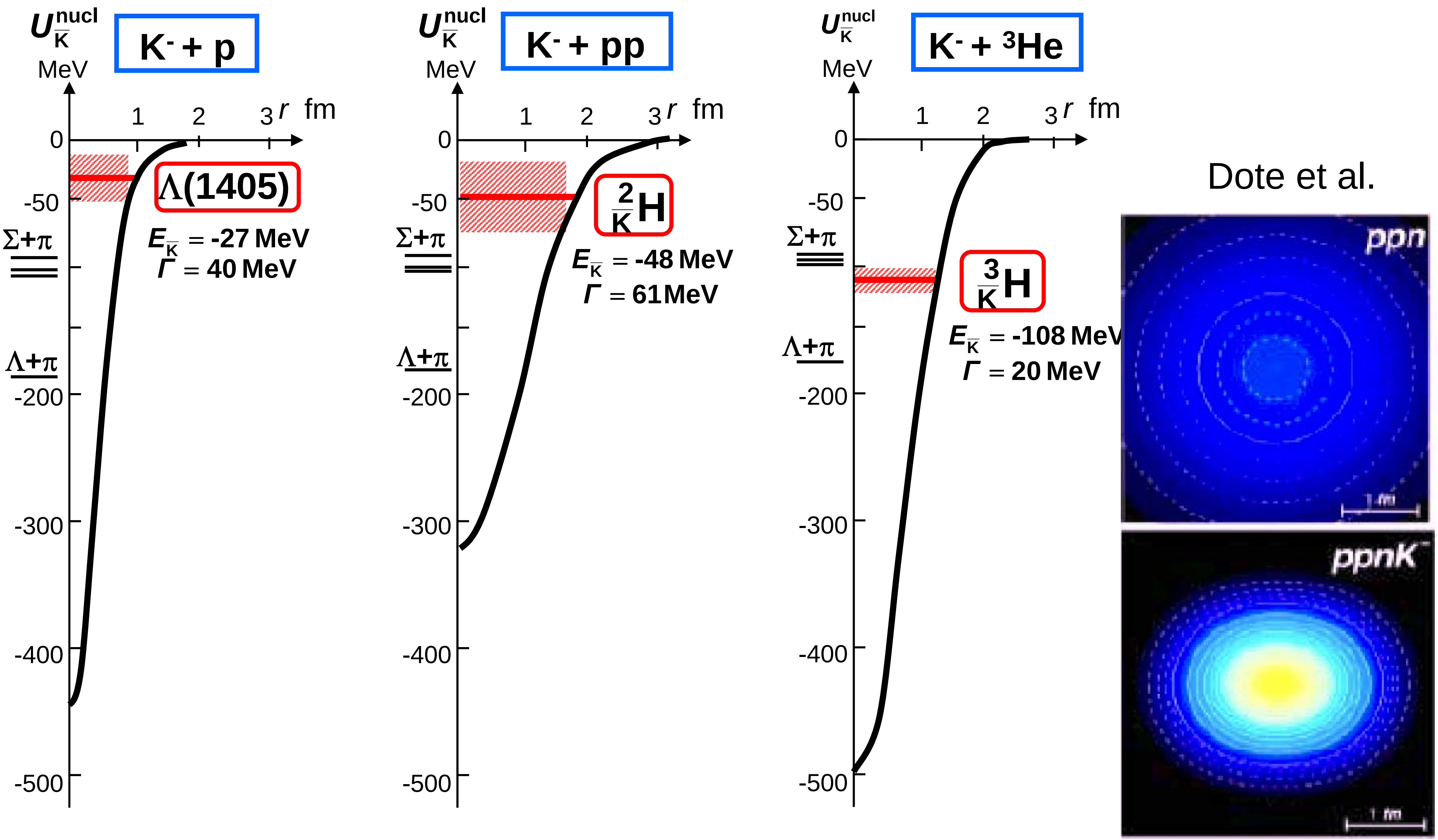
Q: How change the *Hadron Property in Media* ?

related to *(partial) Restoration of Chiral Symmetry*,
may reveal the mechanism of quark condensations.

Kaon in Nuclear Medium

Q: What is happen?

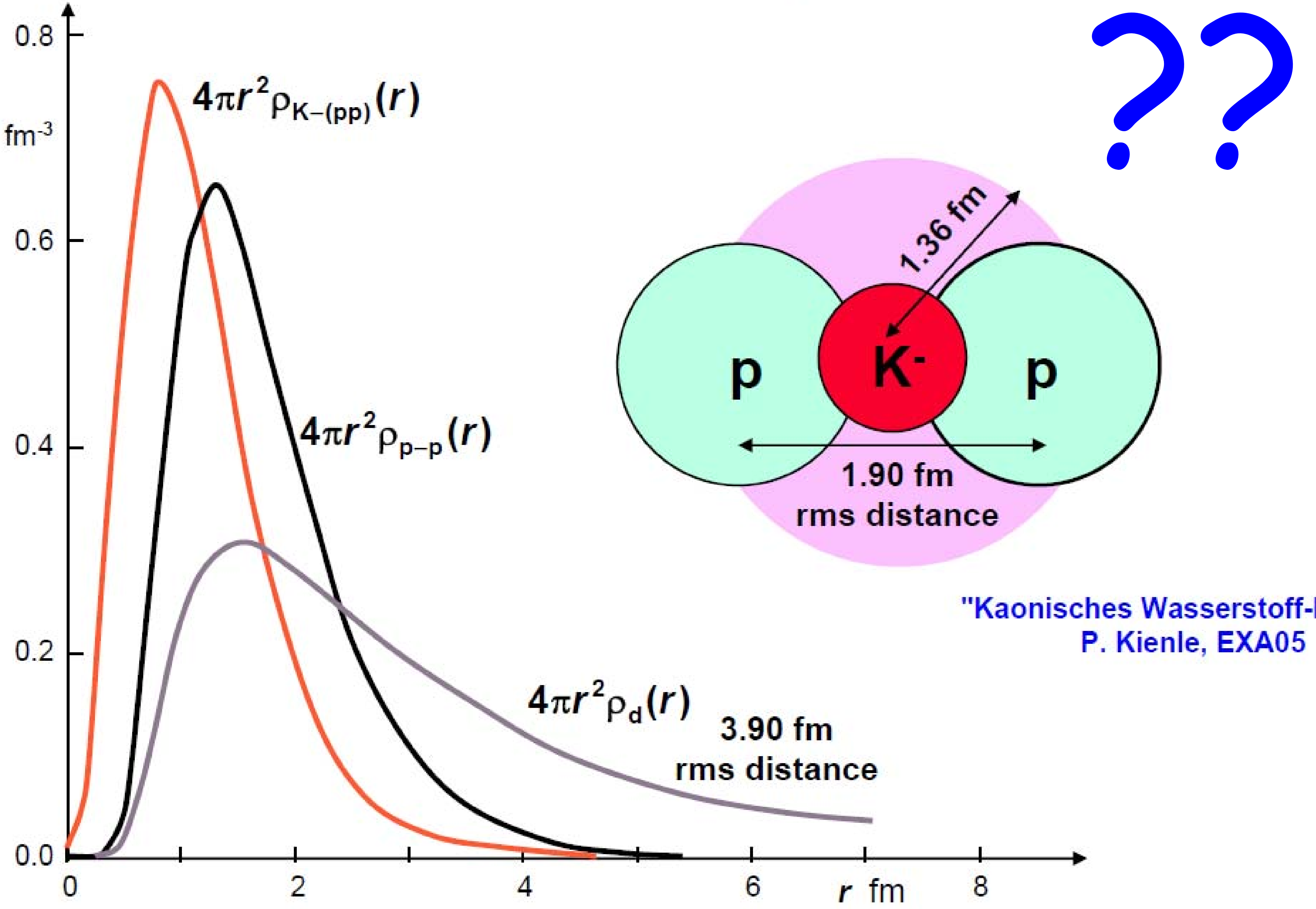
Deeply Bound K^--Nucleus System ?



Y. Akaishi & T. Yamazaki, Phys. Rev. C65 (2002) 044005.

Y. Akaishi & T. Yamazaki, Phys. Lett. B535 (2002) 70.

Structure of ppK$^-$



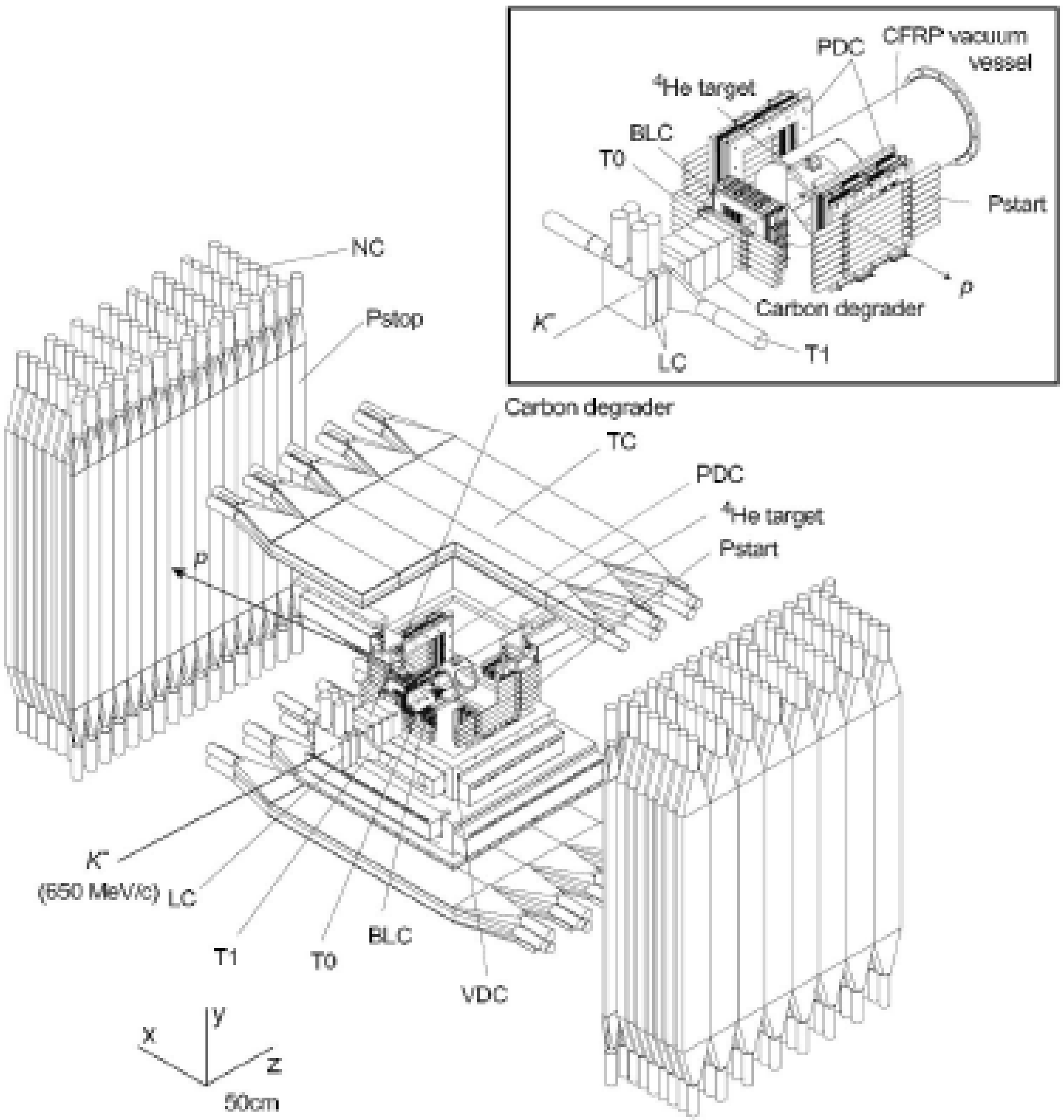
"Kaonisches Wasserstoff-Molekül"
P. Kienle, EXA05

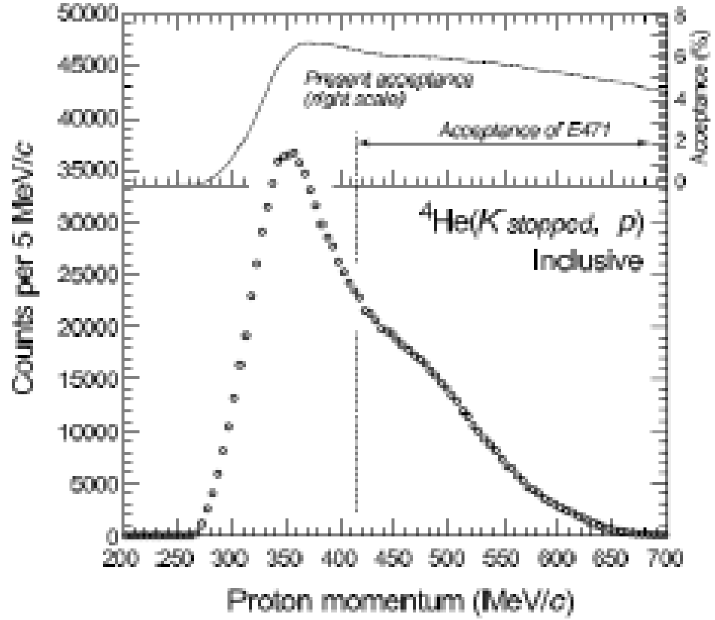
T. Yamazaki & Y. Akaishi, Phys. Lett. B535 (2002) 70.

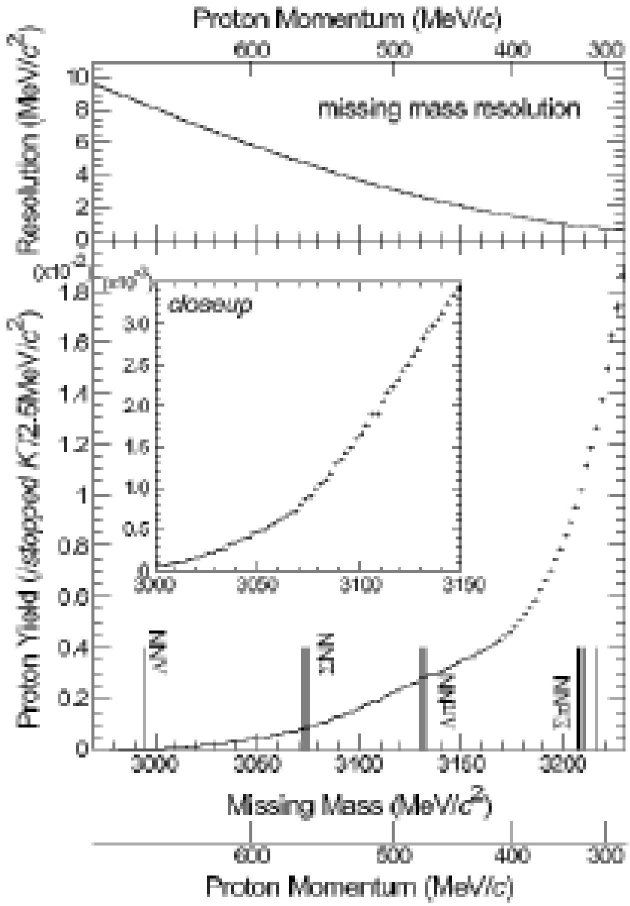
KEK-PS E549実験（M. Iwasaki et al.）

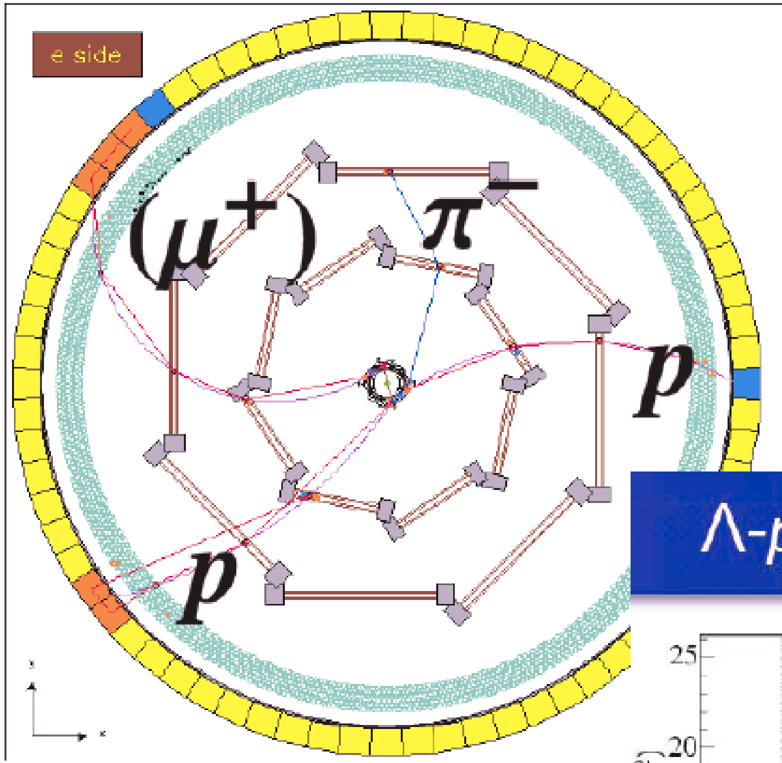
$^4He(K^-$ stopped, N)

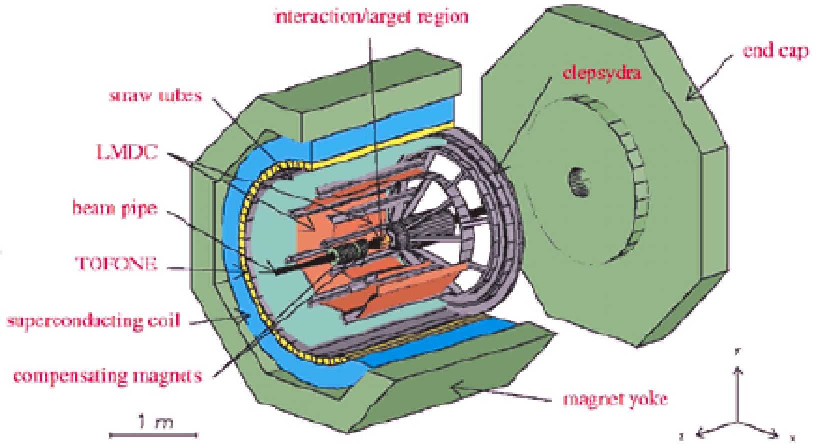
2 Experimental Method





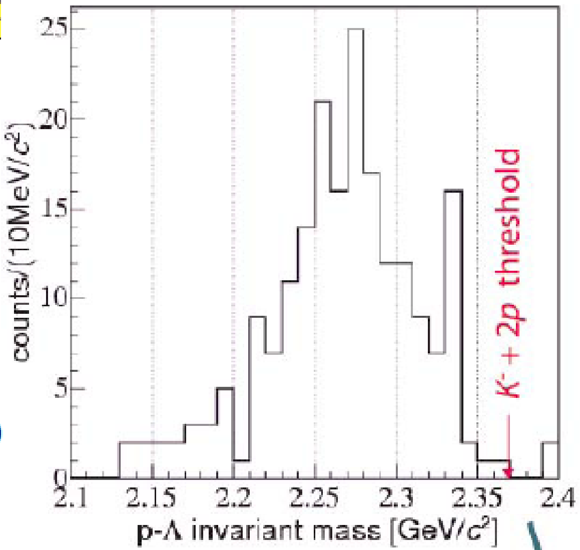




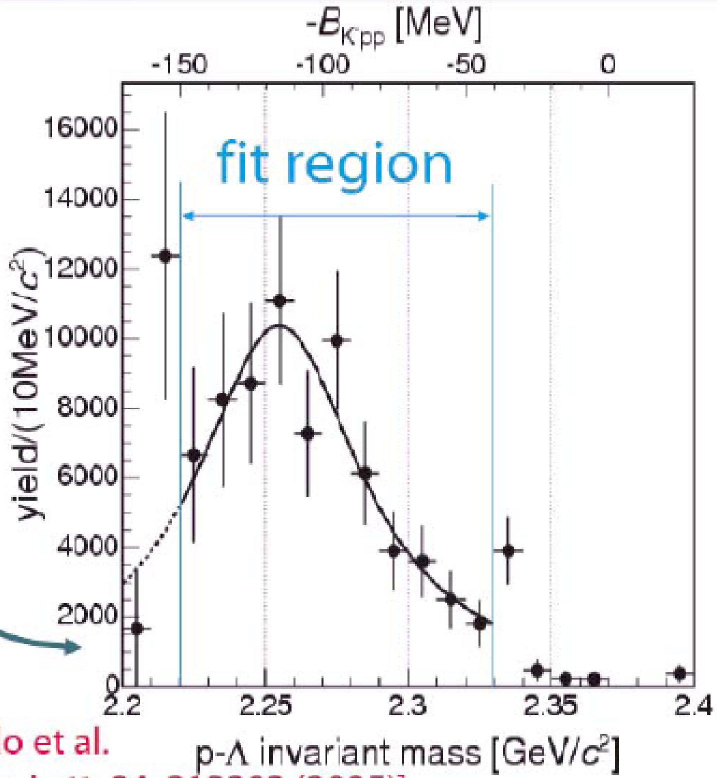


Λ-*p* invariant-mass

YKIS06 藤岡氏のトークより



acceptance correction



FINUDA実験

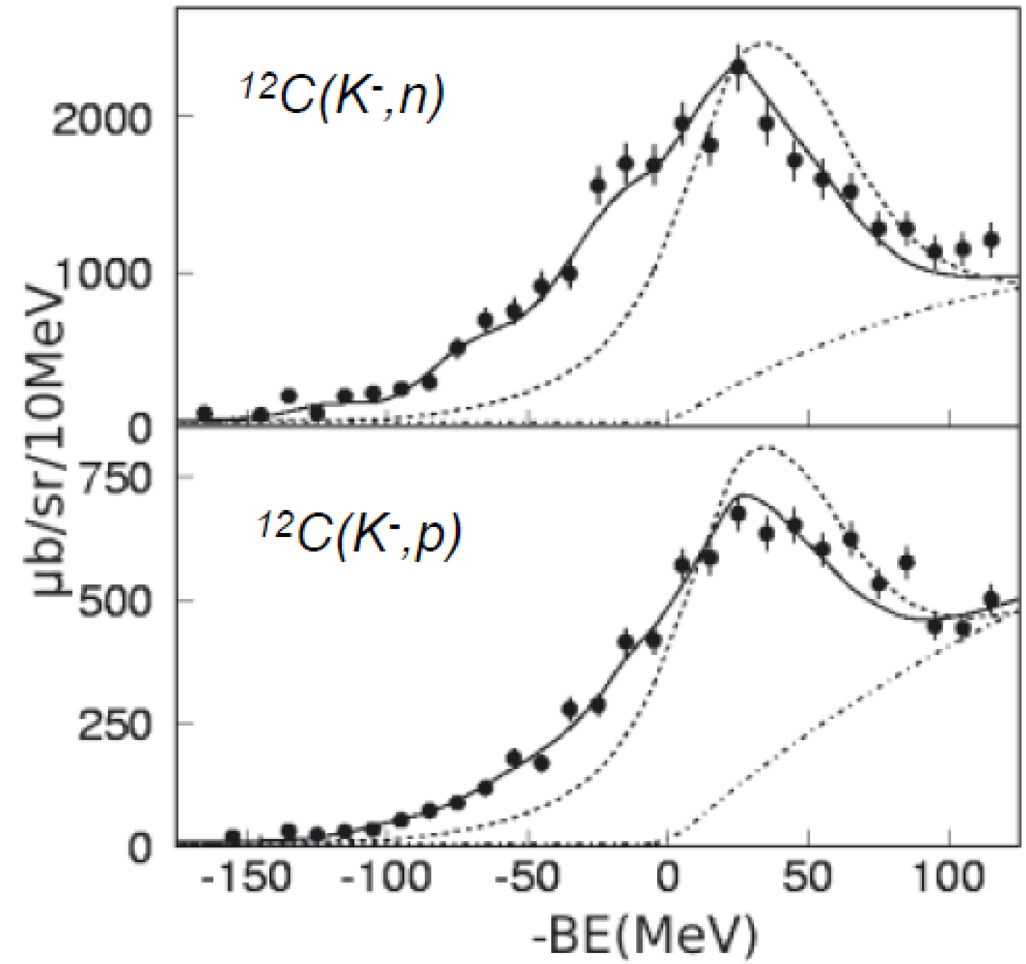
K⁻ stopped on "pp" in A
going to back-to-back Λp

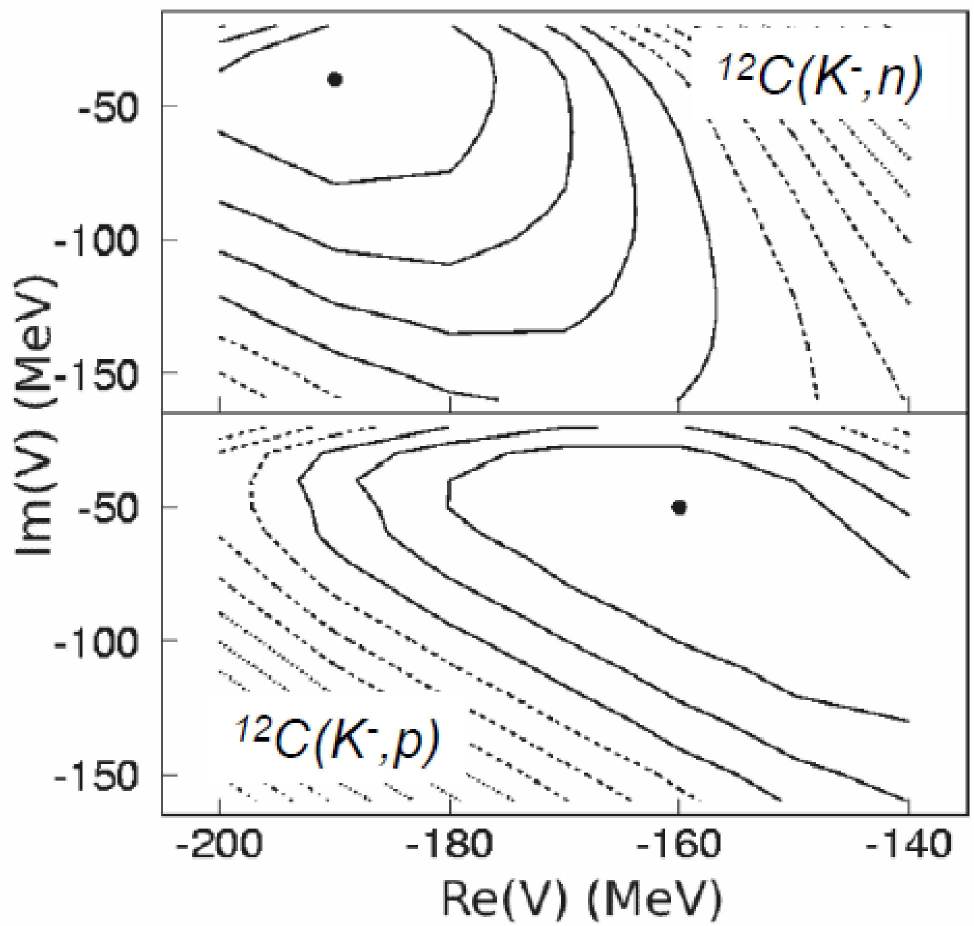
indicating
deeply bound K-pp system!?

$$B = 115\,^{+6}_{-5}\,^{+3}_{-4}\ \mathrm{MeV}$$
$$\Gamma = 67\,^{+14}_{-11}\,^{+2}_{-3}\ \mathrm{MeV}$$

M. Agnello et al.
[Phys. Rev. Lett. 94, 212303 (2005)]

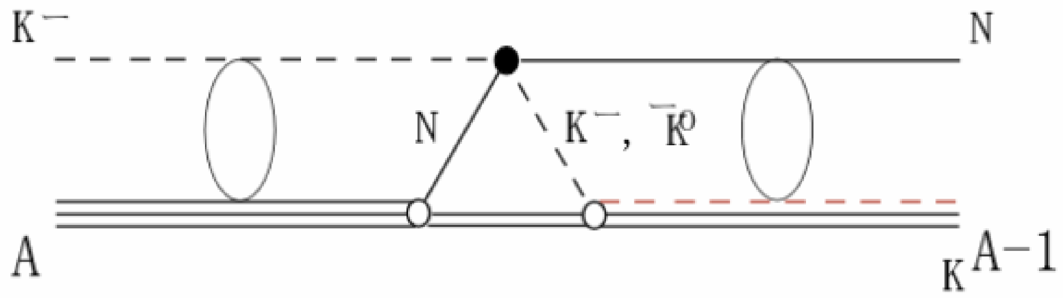
T. Kishimoto et al., PTP118(2007)181





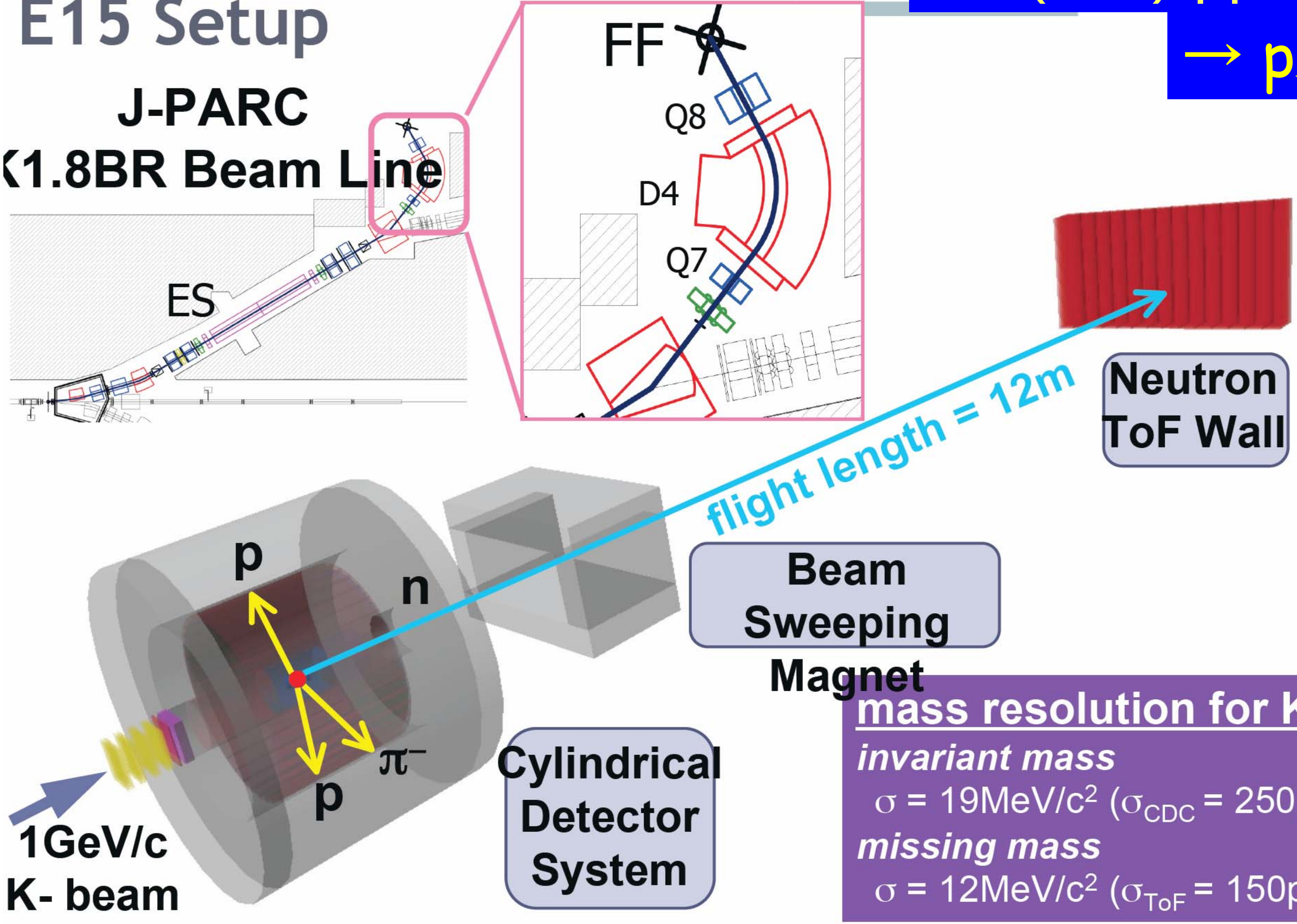
χ^2 contour plot

Fig. 1. Missing mass spectra of the $^{12}C(K^{-},n)$ r
are shown. Solid lines are calculated best fit
Im(V)=-40 MeV (upper) and Re(V)=-160 MeV
lated spectra for Re(V)=-60 MeV and Im(V)=-
process (see text).



E15 Setup

$^{3}He(K^{-},n)$"ppK^{-}" → $p\Lambda$



mass resolution for K-p

invariant mass

σ = 19MeV/c^2 (σ_{CDC} = 250μm

missing mass

σ = 12MeV/c^2 (σ_{ToF} = 150ps)

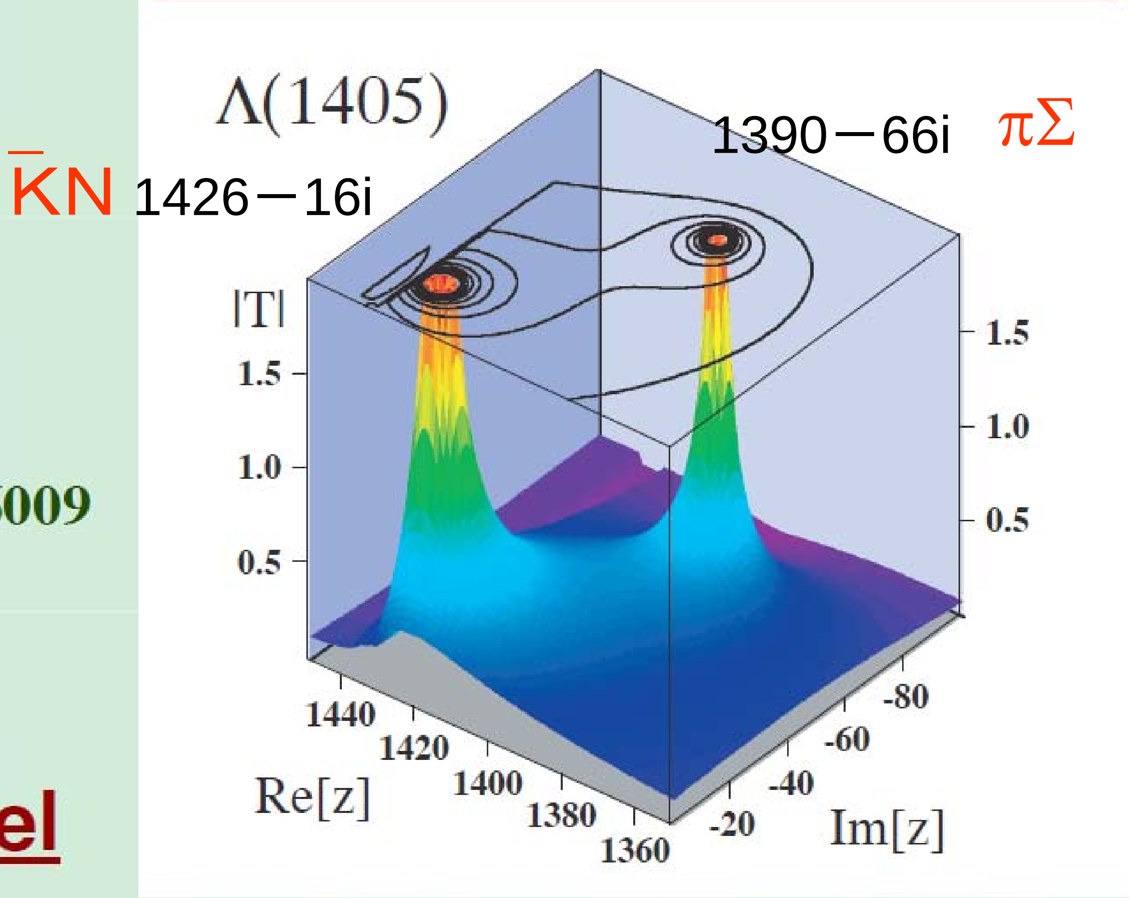
T. Hyodo:
presented in SNP04

Motivation : Two poles?

There are two poles of the scattering amplitude around nominal Λ(1405) energy region.

- **Cloudy bag model**
  J. Fink, *et al.*, PRC41, 2720
- **Chiral unitary model**
  J. A. Oller, *et al.*, PLB500, 263
  E. Oset, *et al.*, PLB527, 99
  D. Jido, *et al.*, PRC66, 025203
  T. Hyodo, *et al.*, PRC68, 018201
  T. Hyodo, *et al.*, PTP112, 73
  C. Garcia-Recio, *et al.*, PRD67, 076009
  D. Jido, *et al.*, NPA725, 181
  T. Hyodo, *et al.*, PRC68, 065203
  C. Garcia-Recio, *et al.*, PLB582, 49
- **Correlated quark model**
  A. Zhang, *et al.*, hep-ph/0403210

$\Lambda(1405) : J^P = 1/2^-, I = 0$

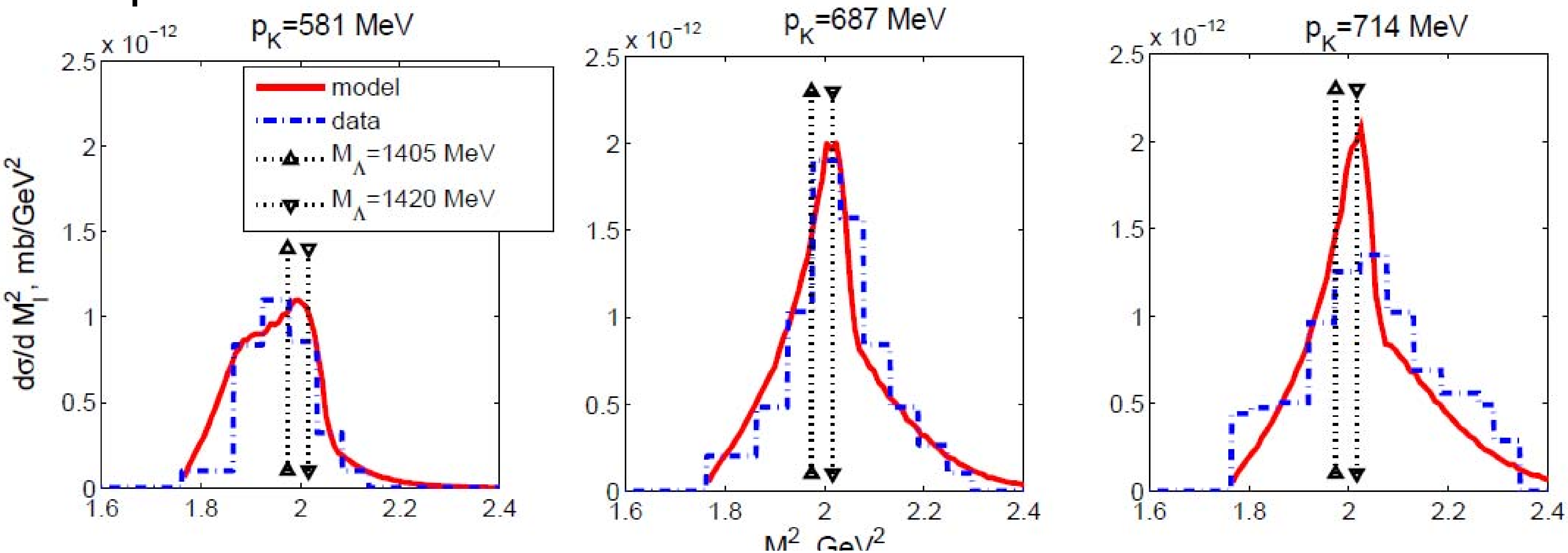


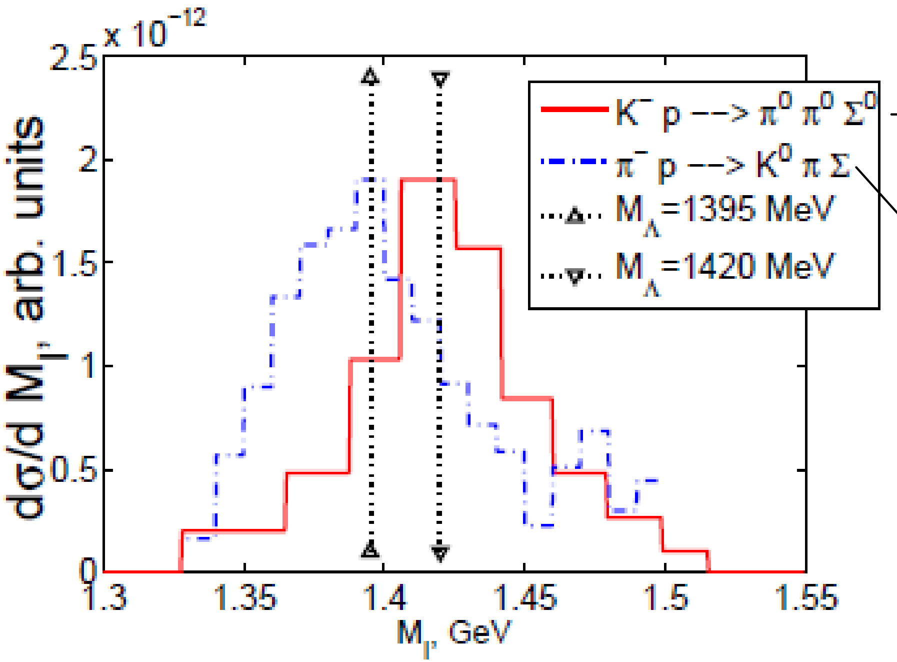
ChU model, T. Hyodo

Evidence for the Two Pole structure of Λ(1405) !?

$K^{-}p \rightarrow \pi^0\pi^0\Sigma^0$

V.K. Magas, E. Oset, A. Ramos, PRL95, 052301(2005)





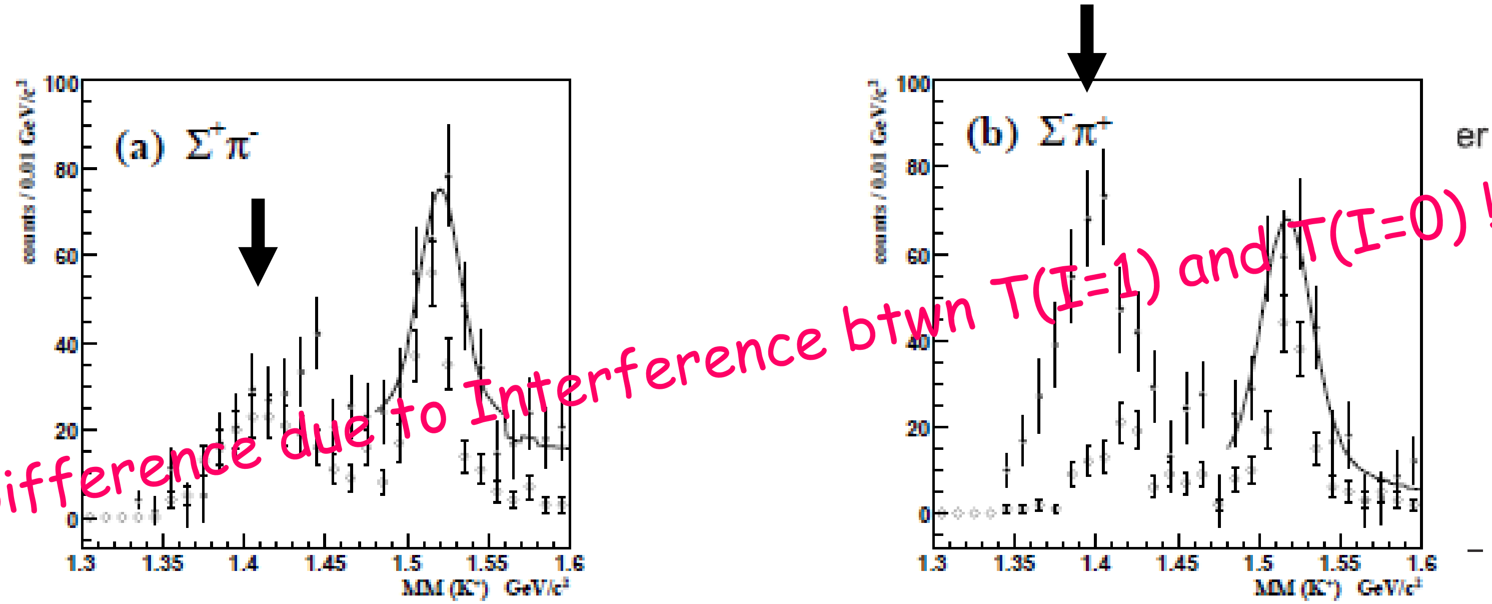
S. Prakhov et al., PRC70, 034605('04)

$K^{-}p \rightarrow \pi^0\pi^0\Sigma^0$

D. W. Thomas et al., NPB56, 15('73)

$\pi^{-}p \rightarrow K^0\pi\Sigma$

LEPS EXP. for $\gamma p \to K^+\pi^-\Sigma^+$ or $\to K^+\pi^+\Sigma^-$:

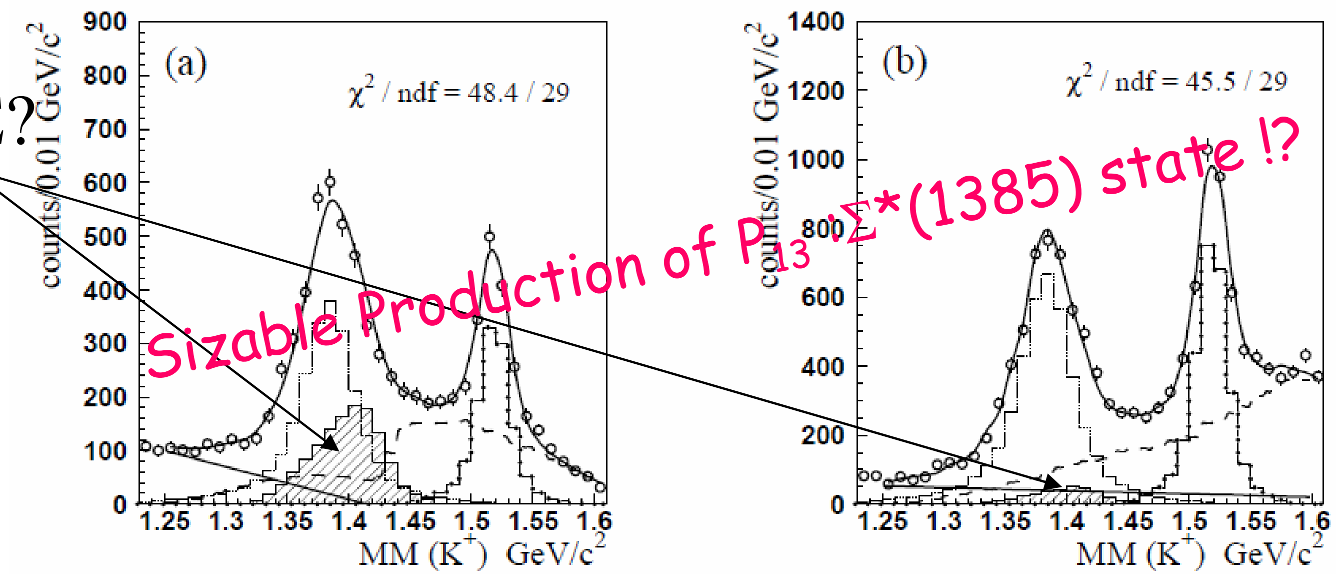


Difference due to Interference btwn T(I=1) and T(I=0) !?

1.5<Eγ<2.0 GeV/c

2.0<Eγ<2.4 GeV/c

$\Lambda^* \to \pi\Sigma$?



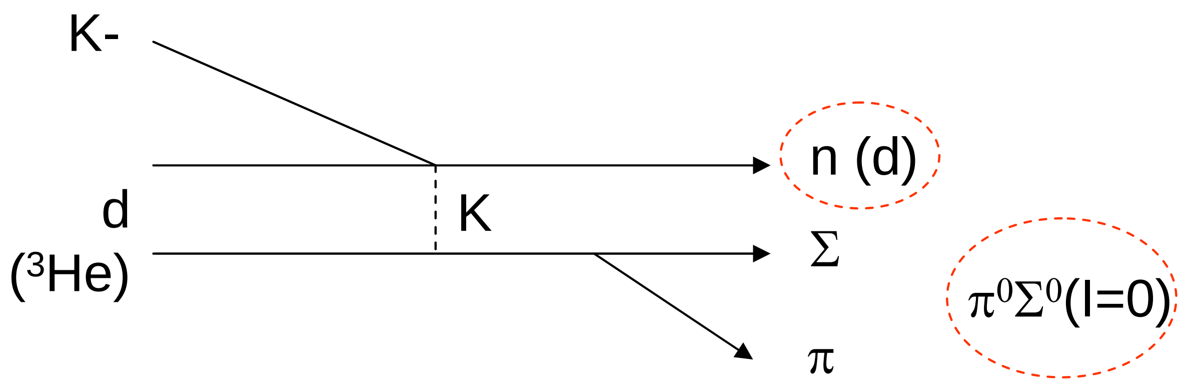
Sizable Production of P_{13} '$\Sigma^*(1385)$ state !?

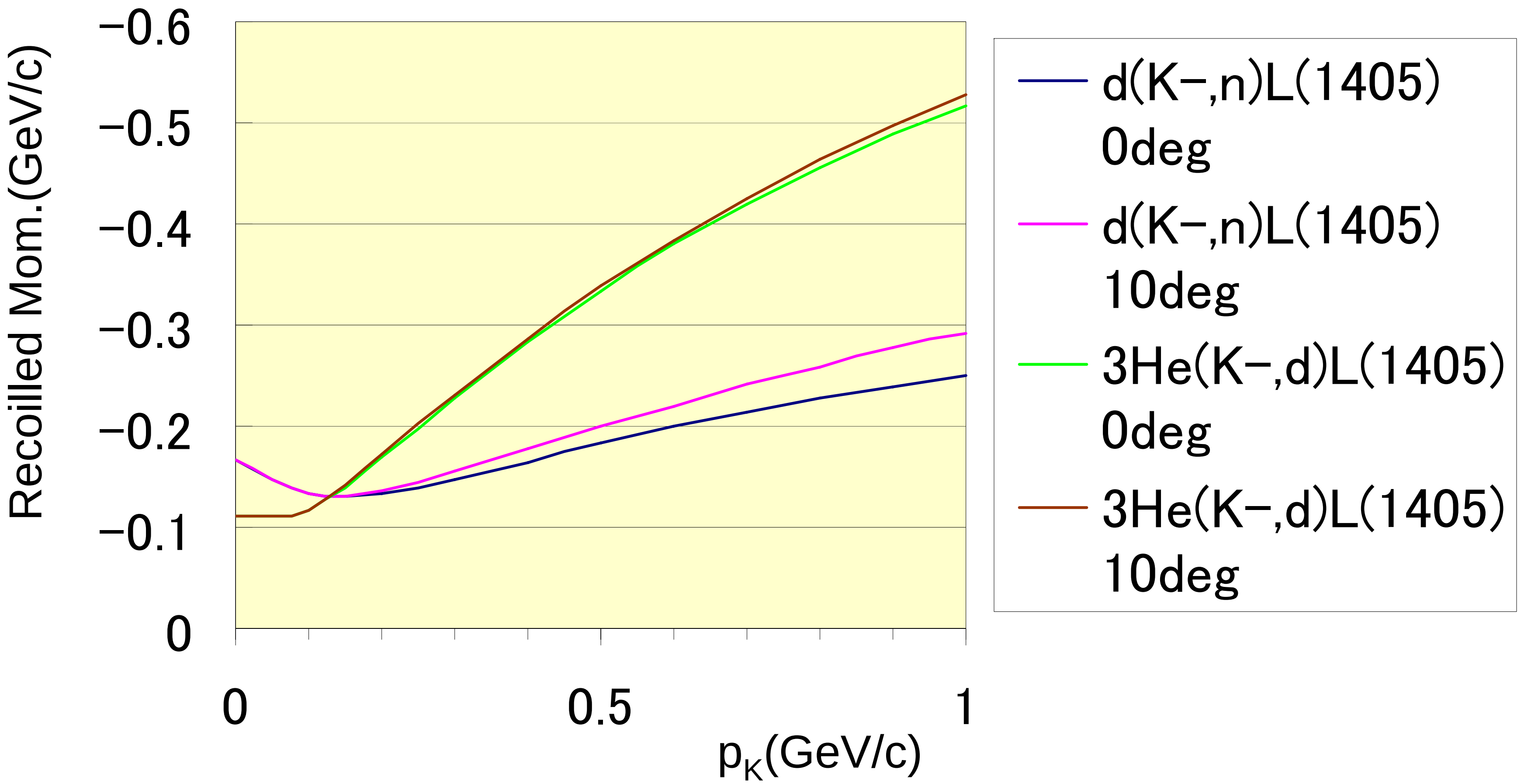
M. Niiyama et al., arXiv:0805.4051v1 [hep-ex] 27 May 2008

Exp. to form S-Wave $\bar{K}N$ state and I=0 state in final state with low-E K- Beam at J-PARC

K-d → nπΣ

K-3He → dπΣ





Electromagnetic Property of Hypernucleus

...provides
more detail/direct information on the dynamics of hadrons in nuclear medium.

The magnetic moment, μ, is described as

$$\mu = \langle \psi^*(m=J)|\mathcal{M}_z|\psi(m=J) \rangle$$

$$\mathcal{M} = \int \boldsymbol{r} \times \boldsymbol{j}(\boldsymbol{r}) \mathrm{d}\boldsymbol{r}$$

$\boldsymbol{j}$: represents the *current* distribution (of constituents) in the nucleus

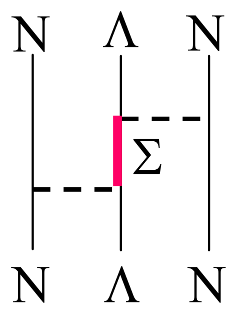
$\mathcal{M}$: magnetic dipole operator, $\mathcal{M}$ (M1)

Naive Picture: single-particle orbital motion + Intrinsic spin

$$\mathcal{M}(M1) \sim \Sigma_i^A (g_\ell^i \boldsymbol{\ell}_i + g_s^i \boldsymbol{s}_i)$$ *i.e.* Schmidt value

Correction:

- medium modification by implication of Y
  core polarization
- exchange current (BB interaction in medium)
  $\Lambda\Sigma$ coupling effect (Isospin$\neq$0)
- hadron modification in medium



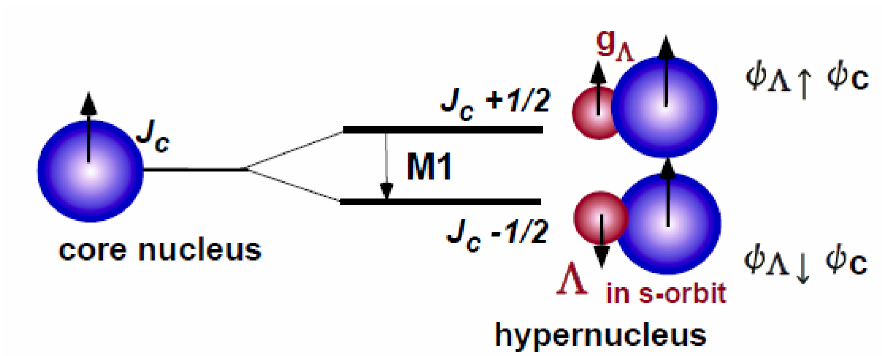
Approach to the Λ hypernuclear Magnetic Moment:

✓ Indirect measurement → τ, B(M1)

proposed by H. Tamura (Tohoku) et al.

- Doppler Shift Attenuation Method:

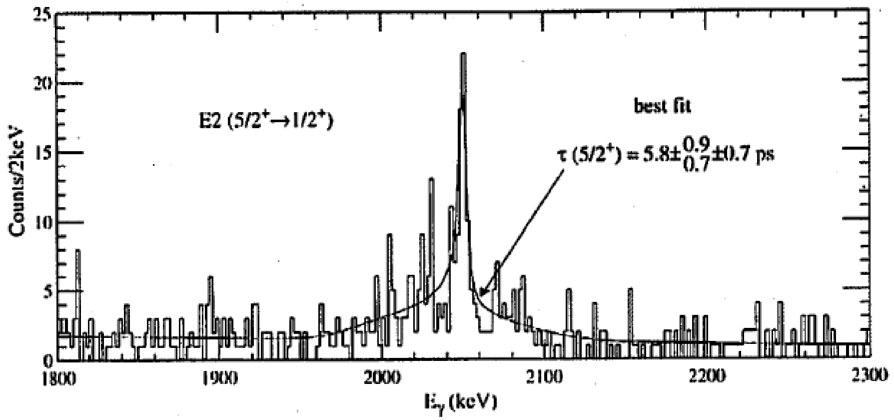
$B(M1) \sim |\langle f|\mu_z|i\rangle|^2 \sim (g_C - g_\Lambda)^2$



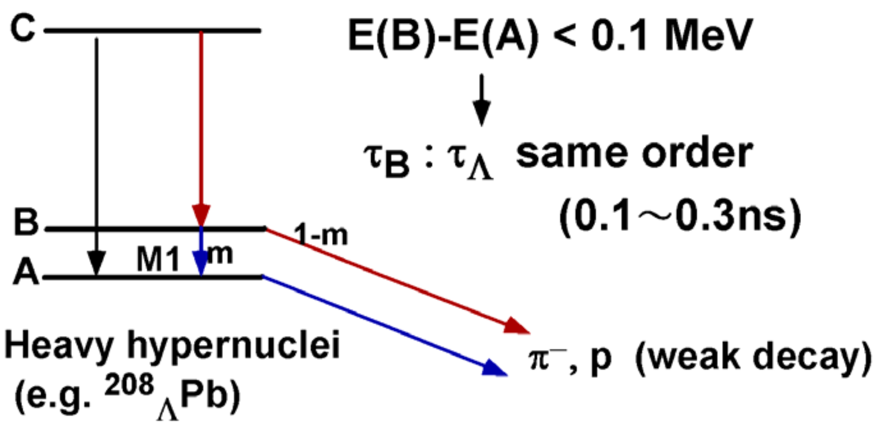
K. Tanida et al. PRL86, 1982(2001)

c.f. $\tau^{-1} \sim B(E2) \sim 3.6 +- 0.5^{+0.5}_{-0.4}$ [e^2fm^4]

→ Q-moment~$\langle R^4 \rangle$

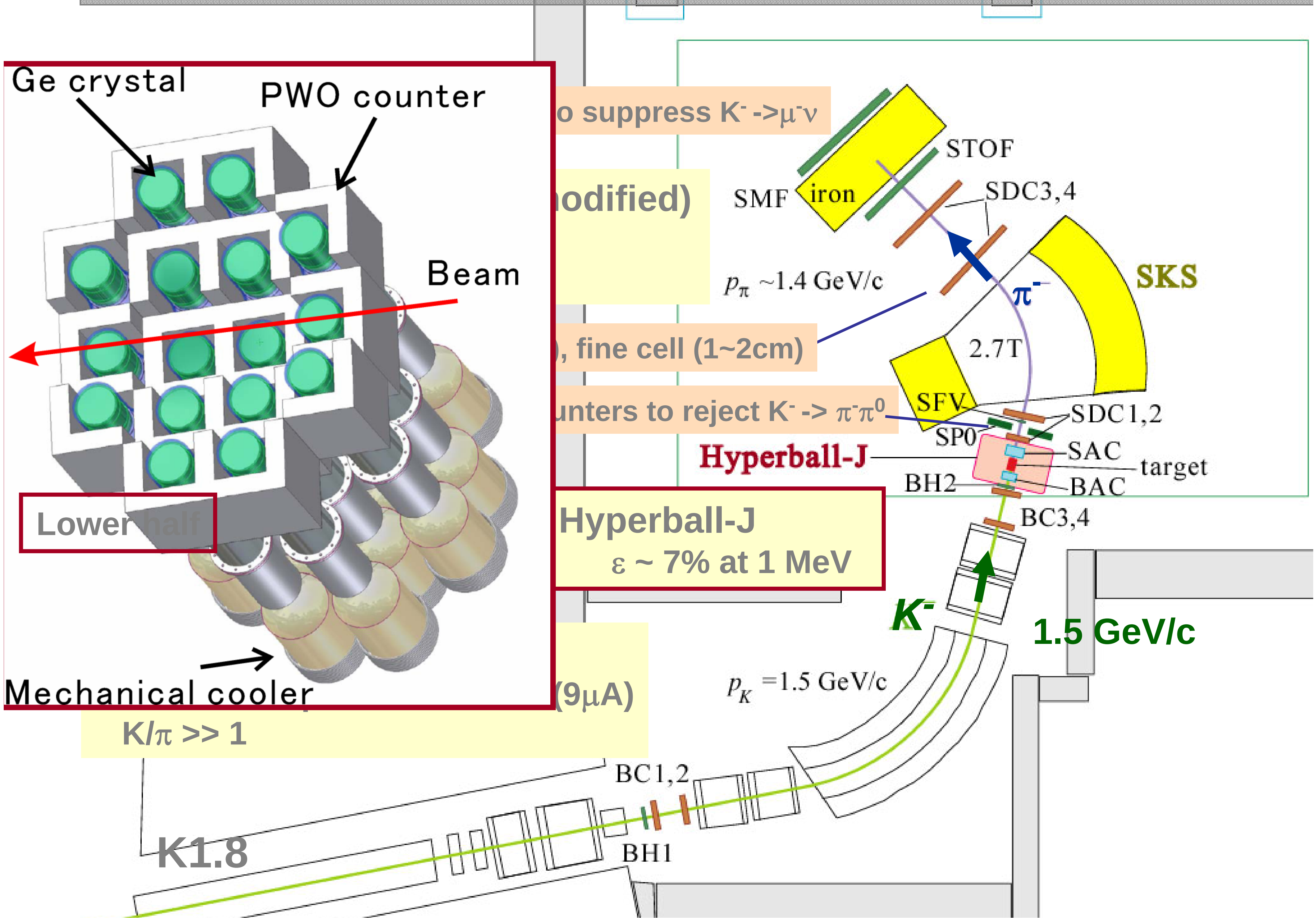


- γ-Weak Coincidence Method:



✓ Direct measurement

Beam and Setup for γ spectroscopy

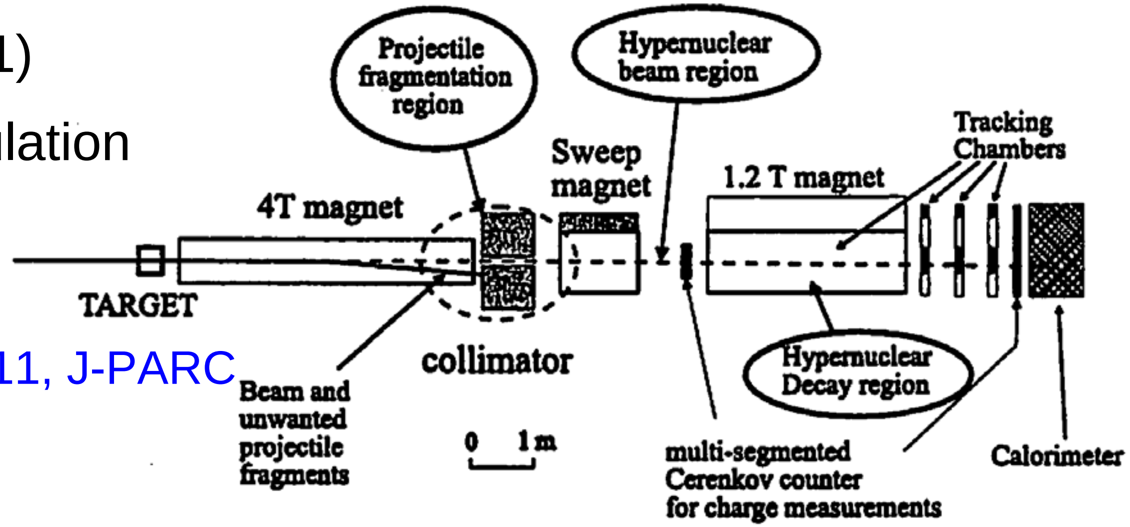


Approach to the Λ hypernuclear Magnetic Moment:

✓ Direct measurement : precession in Strong Magnetic Field

Independent measurement of B(M1)

detail analysis w/ precise calculation



- Relativistic HF:

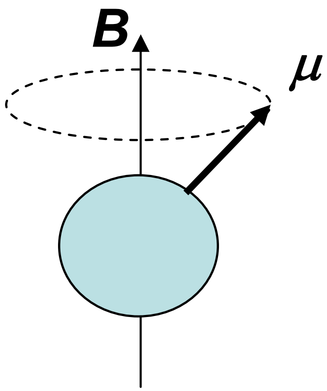
M. Asakawa et al. KEK Rep. 2000-11, J-PARC

T. Saito et al, GSI/FAIR

The precession angle

can be enhanced by γ(Lorentz Boost) factor.

Promising way, *if significant polarization of HF is proofed.*



- "pionic-decay NMR" from Polarized Hypernuclei:

Polarization of Hypernuclei

Asymmetric weak decay pion:

$$W(\theta)=1 + \Sigma_k a_k P_\Lambda P_k(\theta)$$

(a_k~small for Nonmesonic WD-proton)

H. Ejiri, T. Kishimoto, and HN, PLB225, 35(1989)

P_Λ ~ 0.2 in (π^+,K^+) at 15 deg.

for medium nuclei

Strong Magnetic Field for precession is needed

Hypernuclear Polarization:

Large Polarization is produced via the (π^+,K^+) reaction

Λ Pol. in (π^+,K^+) and (K^-,π^-)

20 *K. Itonaga, T. Motoba and M. Sotona*

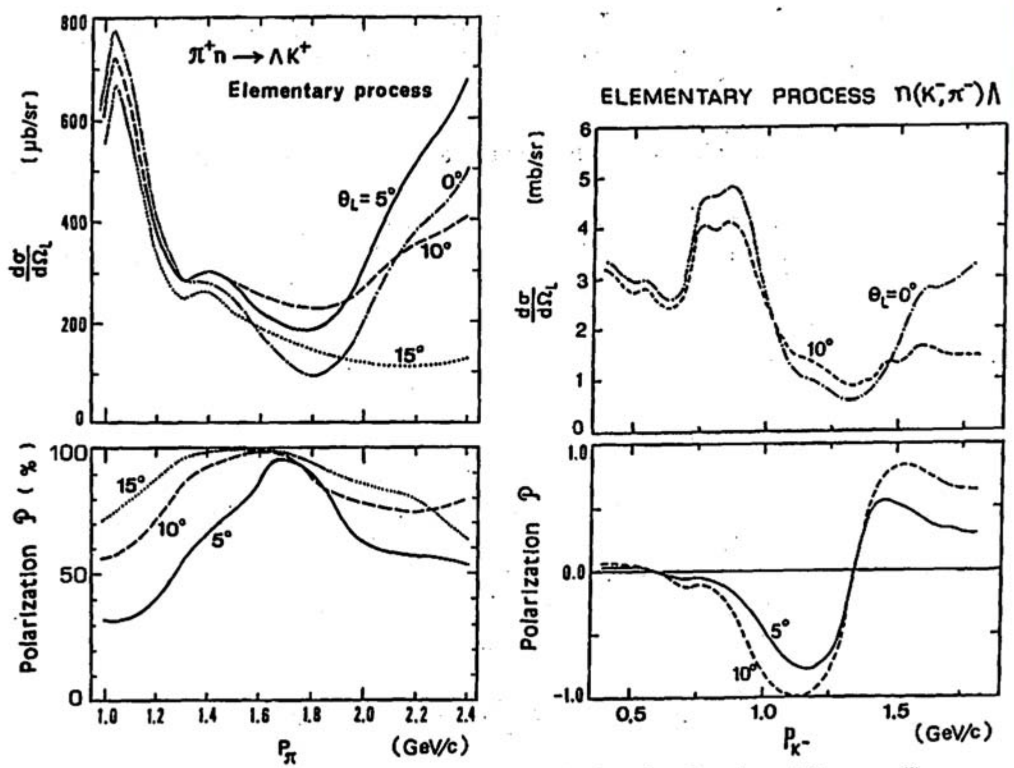


Fig. 1. (left): The elementary cross sections and polarizations for the $\pi^+n\to\Lambda K^+$ process[28] as a function of the incident momentum p_{π^+} and the lab. scattering angle θ_L. (right): Similarly the cross sections and polarizations for the $K^-n\to\Lambda\pi^-$ process.[24]

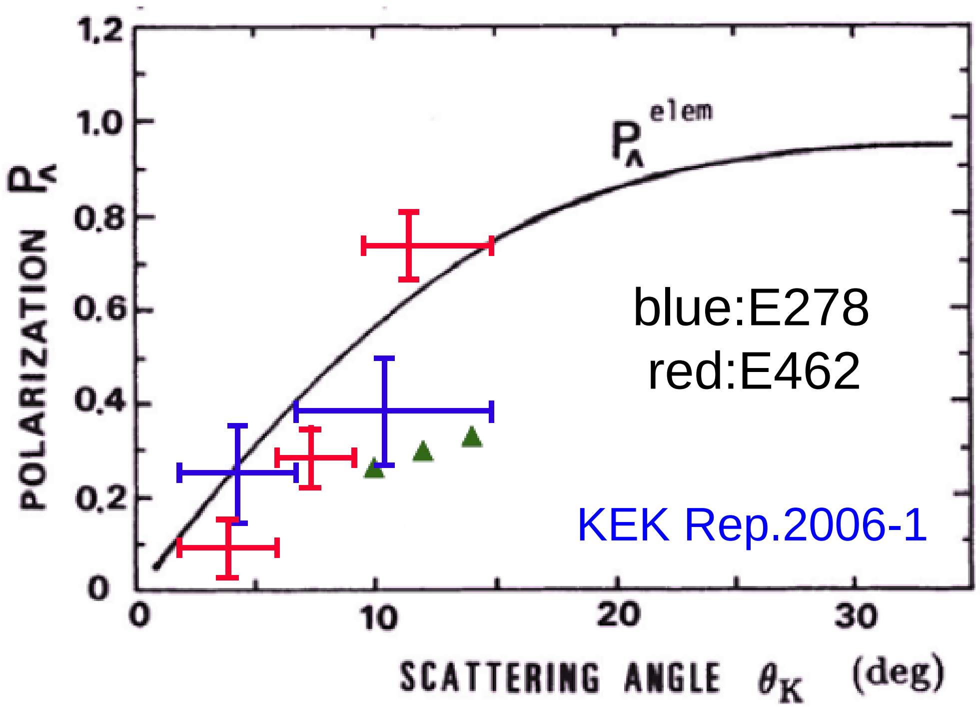
Phase Shift Analysis by
K. Itonaga, T. Motoba, and M. Sotona
PTPsuppl.117, 17(1994)

Measured Pol. of $^5_\Lambda$He produced via (π^+,K^+) on ^{6}Li

$$W(\theta)=1+\alpha P_\Lambda \cos\theta,\ \alpha=-0.642(13)$$

KEK-PS E278
S. Ajimura, PRL84, 4052(2000)

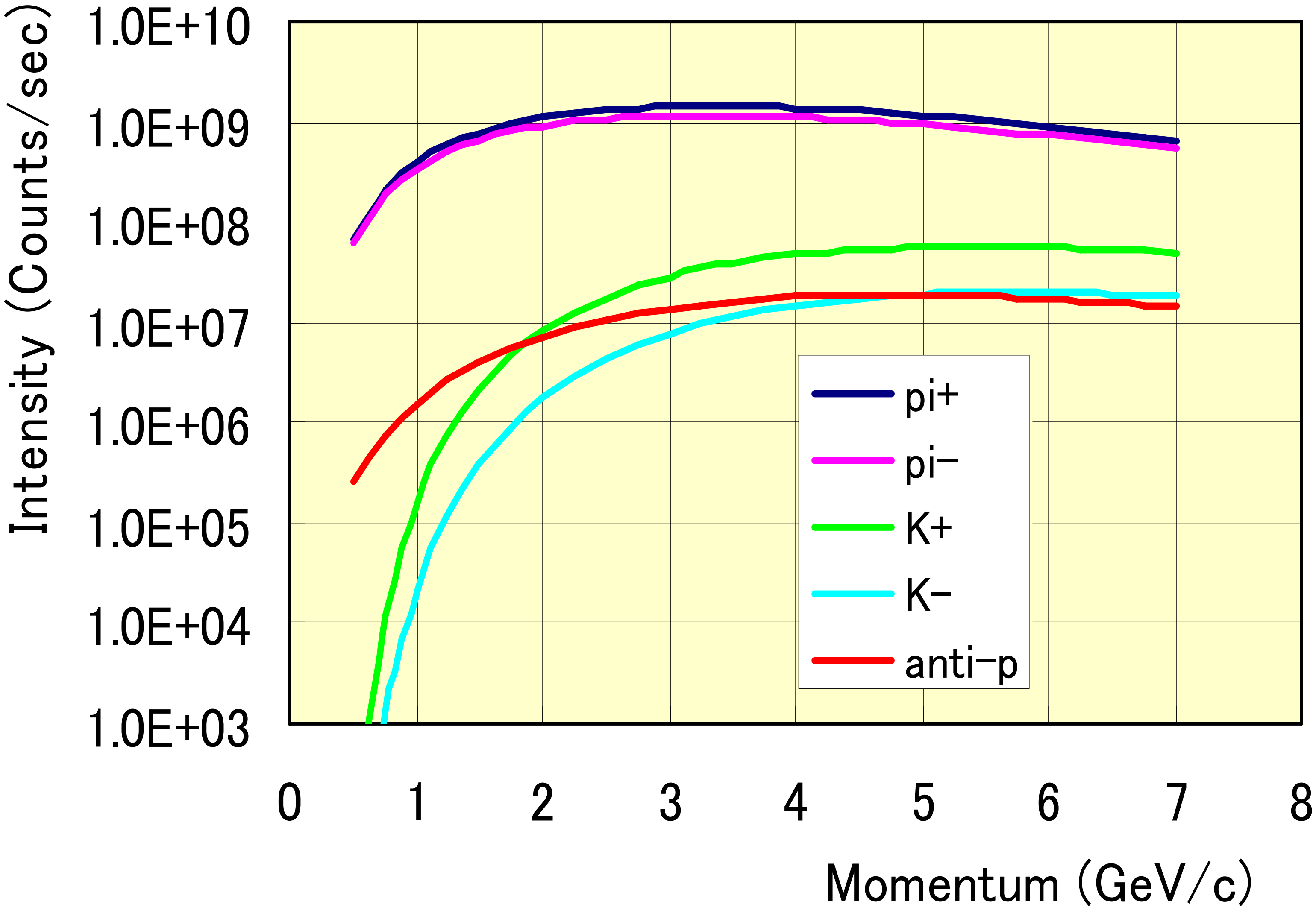
KEK-PS E462
T. Maruta, KEK Rep.2006-1



What a Intense Sencondary Beam is Produced!

Expected Beam Intensity for
50GeV-15μA proton beam on Ni-54mm
BL-Length=50 m, Acceptance:2msr%

by Sanford-Wang



One Possible Solution to handle very high intensity beam is :

High Intensity, High Resolution Beam Line

for

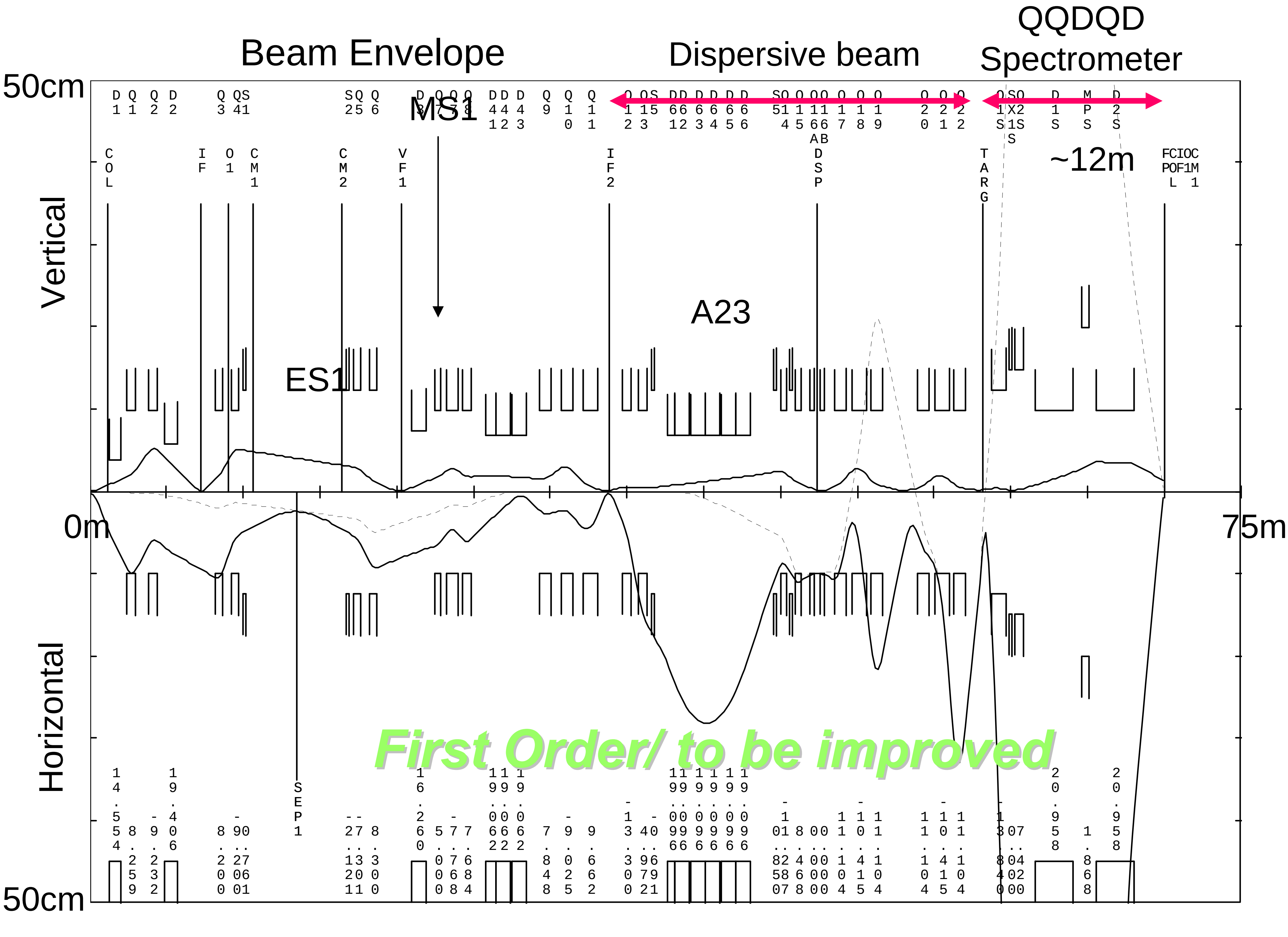
High Statistics and High Precision Spectroscopic Studies

on n-rich Λ hypernuclei

- Provide very intense pion beam of as high as 10^9 Hz
  to overcome a small cross section,
  to use a thin target for a high resolution.
- Dispersive beam at the exp. target and
- Momentum Matching of the Beam Line w/ the Spectrometer
- Realize a High Resolution of dp/p=1/10,000.

×100 higher Statistics
×10 higher resolution

Momentum Matching Beam line and Spectrometer System



Extension of Hadron Hall

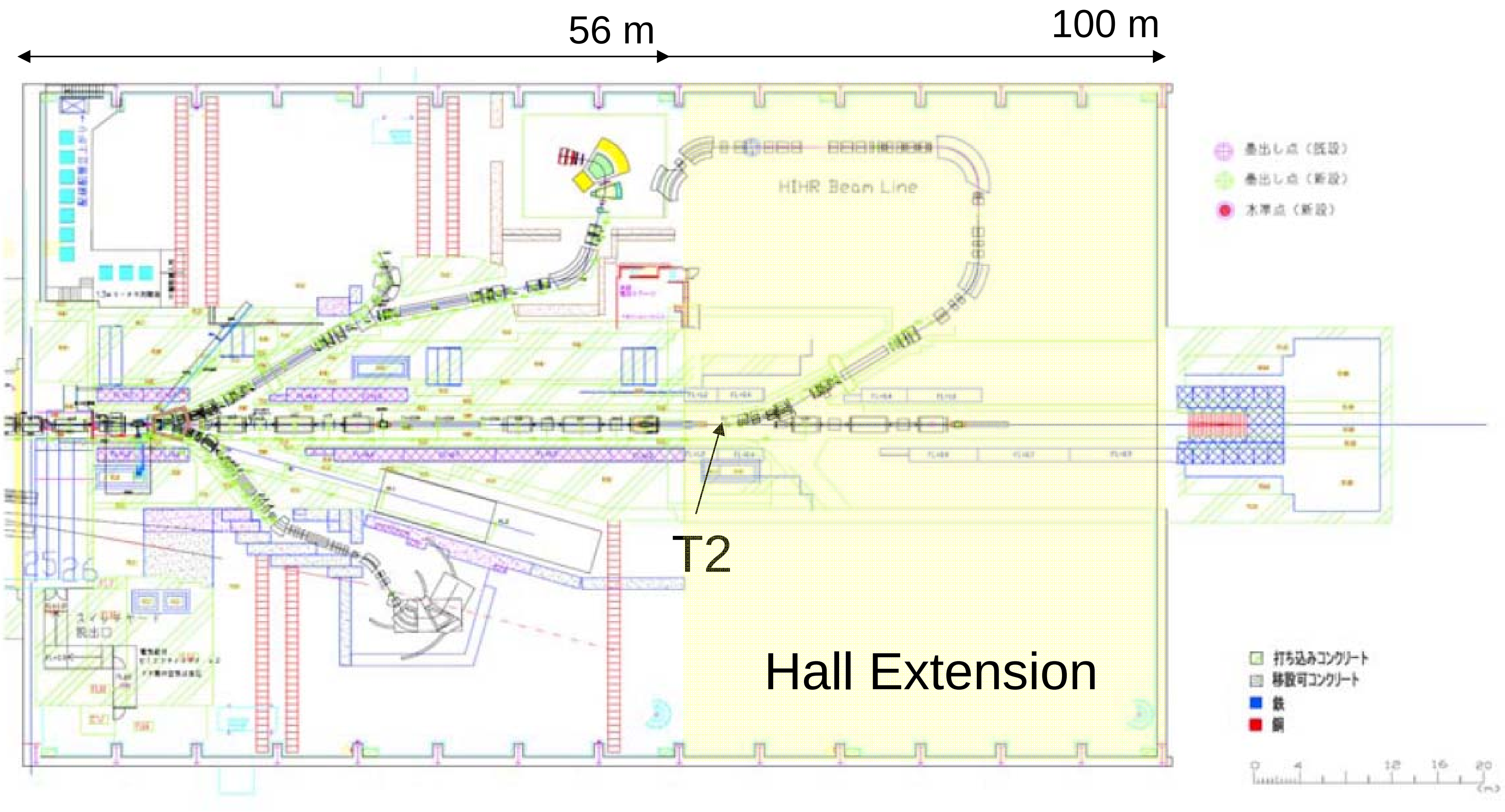


Fig. 1: An example of layout plan of High Intensity, High Resolution (HIHR) Beam Line connected to the T2 target in the extended Hadron Experimental Hall.

as a SUMMARY...

- ✓ J-PARC Beam will be coming soon (at the end of 2008).
  J-PARC is only a Kaon Factory in the world,
  which will provide a lot of Unique and Good opportunities
  to study Nuclear and Particle Physics.

- ✓ J-PARC has to be an International Facility.
  Particularly,
  It is important to form International Collaborations.
  →Hadron User's Association, founded March, 2007
  http://www.rcnp.osaka-u.ac.jp/~jparchua/en/index.html

- ✓ The Hadron Exp. Hall is to be extended to accommodate
  Many Forth-coming Future Physics Experiments.

Please Come and Join Us!