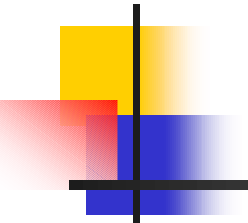




Strangeness Nuclear Physics experiments at 50-GeV PS

Tomofumi Nagae
KEK

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- LOI for the Experiments on Strangeness Nuclear Physics at the 50-GeV Proton Synchrotron, [July, 2000](#).
 - K. Imai, T. Nagaе, M. Ieiri, H. Noumi, T. Fukuda, H. Outa, K. Nakazawa, K. Yamamoto, T. Yoshida, O. Hashimoto, H. Tamura, T. Takahashi, Y. Fujii, T. Kishimoto, K. Tanida, B. Bassalleck
 - http://www-jhf.kek.jp/JHF_WWW/LOI/50GeVNP-LOI-v1.0.pdf or visit <http://jkj.tokai.jaeri.go.jp/NuclPart/Science.html>



Contents of LOI

- Introduction
- Spectroscopic Study of $S=-2$ Systems
- Hyperon Proton Scattering
- Hypernuclear γ -ray spectroscopy
- High-Resolution Reaction Spectroscopy of $S=-1$ Hypernuclei
- Study of Dense Nuclear Matter with Strangeness

What's “*strange*” in Strangeness Nuclear Physics ?

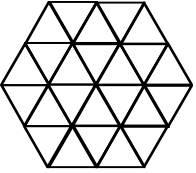
- Nothing strange...
 - Natural extension into $SU(3)_F$
 - Many-Body Theory; Applicable

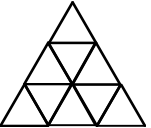


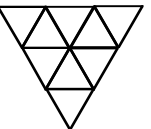
- What about “*Nuclear Force*” extended in $SU(3)_F$?
 - Lack of understanding on QCD in this scale
 - Lack of experimental data


Baryon-Baryon Interaction


バリオン-バリオン系のSU(3)による分類

27_s  $S=0$ NN(T=1)
 $S=-1$ $\Sigma N(T=3/2)\Sigma N-\Lambda N(T=1/2)$
 $S=-2$ $\Sigma\Sigma(T=2)\Xi N-\Sigma\Lambda-\Sigma\Sigma(T=1)\Xi N-\Sigma\Sigma-\Lambda\Lambda(T=0)$
 $S=-3$ $\Xi\Sigma(T=3/2)\Xi\Sigma-\Xi\Lambda(T=1/2)$
 $S=-4$ $\Xi\Xi(T=1)$

10_a  $S=0$ NN(T=0)
 $S=-1$ $\Sigma N-\Lambda N(T=1/2)$
 $S=-2$ $\Xi N-\Sigma\Lambda(T=1)$
 $S=-3$ $\Xi\Sigma(T=3/2)$

10_a  $S=-1$ $\Sigma N(T=3/2)$
 $S=-2$ $\Xi N-\Sigma\Lambda-\Sigma\Sigma(T=1)$
 $S=-3$ $\Xi\Sigma-\Xi\Lambda(T=1/2)$
 $S=-4$ $\Xi\Xi(T=0)$

8_s  $S=-1$ $\Sigma N-\Lambda N(T=1/2)$
 $S=-2$ $\Xi N-\Sigma\Lambda(T=1)\Xi N-\Sigma\Sigma-\Lambda\Lambda(T=0)$
 $S=-3$ $\Xi\Sigma-\Xi\Lambda(T=1/2)$

8_a  $S=-1$ $\Sigma N-\Lambda N(T=1/2)$
 $S=-2$ $\Xi N-\Sigma\Lambda-\Sigma\Sigma(T=1)\Xi N(T=0)$
 $S=-3$ $\Xi\Sigma-\Xi\Lambda(T=1/2)$

1_s  $S=-2$ $\Xi N-\Sigma\Sigma-\Lambda\Lambda(T=0)$

Understanding of the flavor SU(3) baryon-baryon interaction

- Y-N, Y-Y < N-N ?
Repulsive or Attractive ?
- Repulsive cores in Y-N/Y-Y ?
What's the origin ?
- Spin-dependent forces in Y-N/Y-Y.
- Dibaryons ?

Strangeness Nuclear Physics
with
50 GeV Intense Hadron Accelerator

High Intensity K^- Beam $\sim 10^7/s$

S=-1
High-Resolution Spectroscopy

- Gamma Spectroscopy
- Heavy Λ Hypernuclei
- Polarized Λ Hypernuclei
- Σ Hypernuclei

$(\pi^+, K^+)\gamma$
 $(K^-, \pi^-)\gamma$

Weak Y-N, Y-Y Interactions

S=-2
Hypernuclei

- Ξ Hypernuclei
- $\Lambda\Lambda$ Hypernuclei
- H Particle

(K^-, K^+)

Y-N Scatterings
S=-2

- Ξp

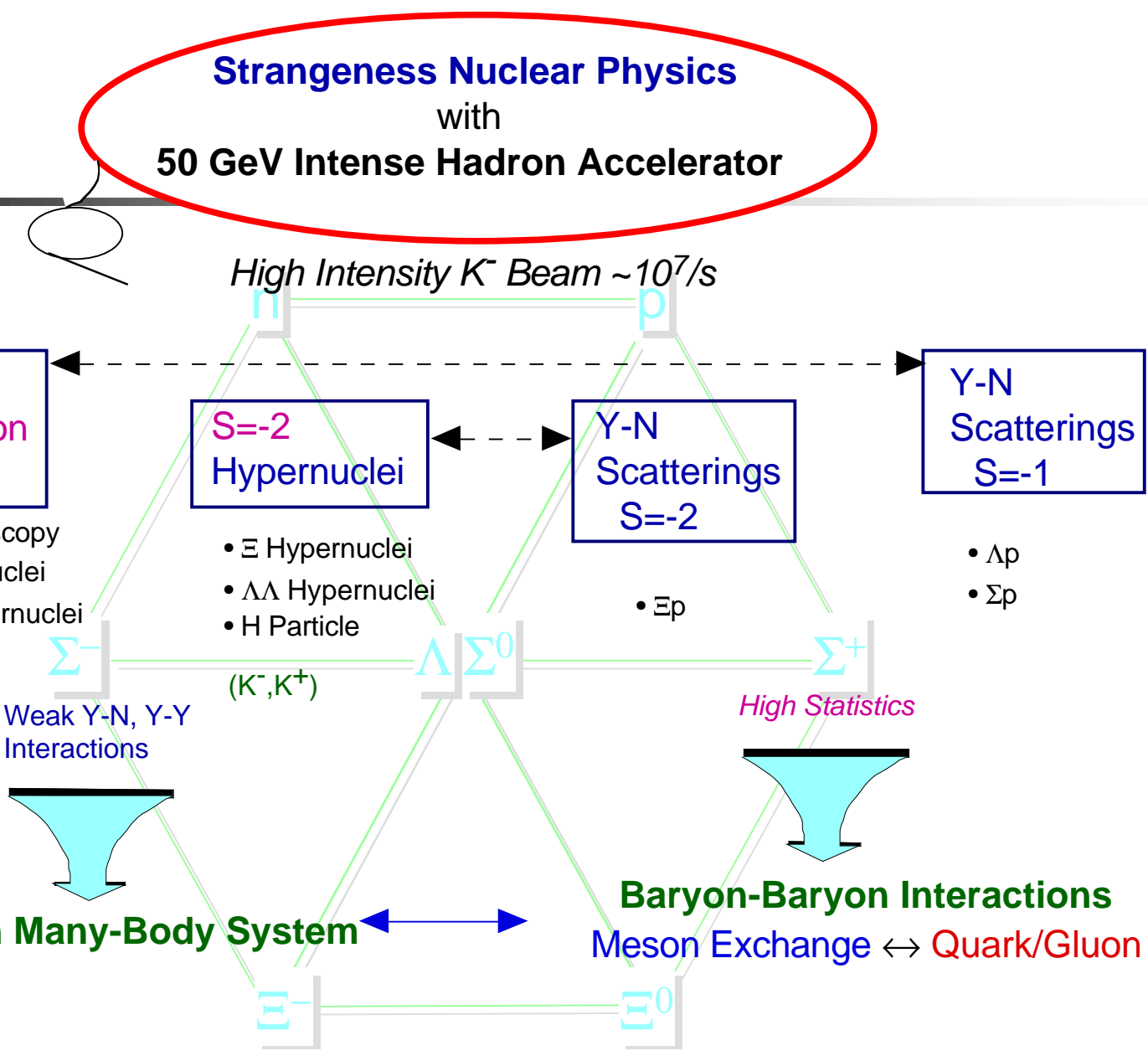
Y-N Scatterings
S=-1

- Λp
- Σp

High Statistics

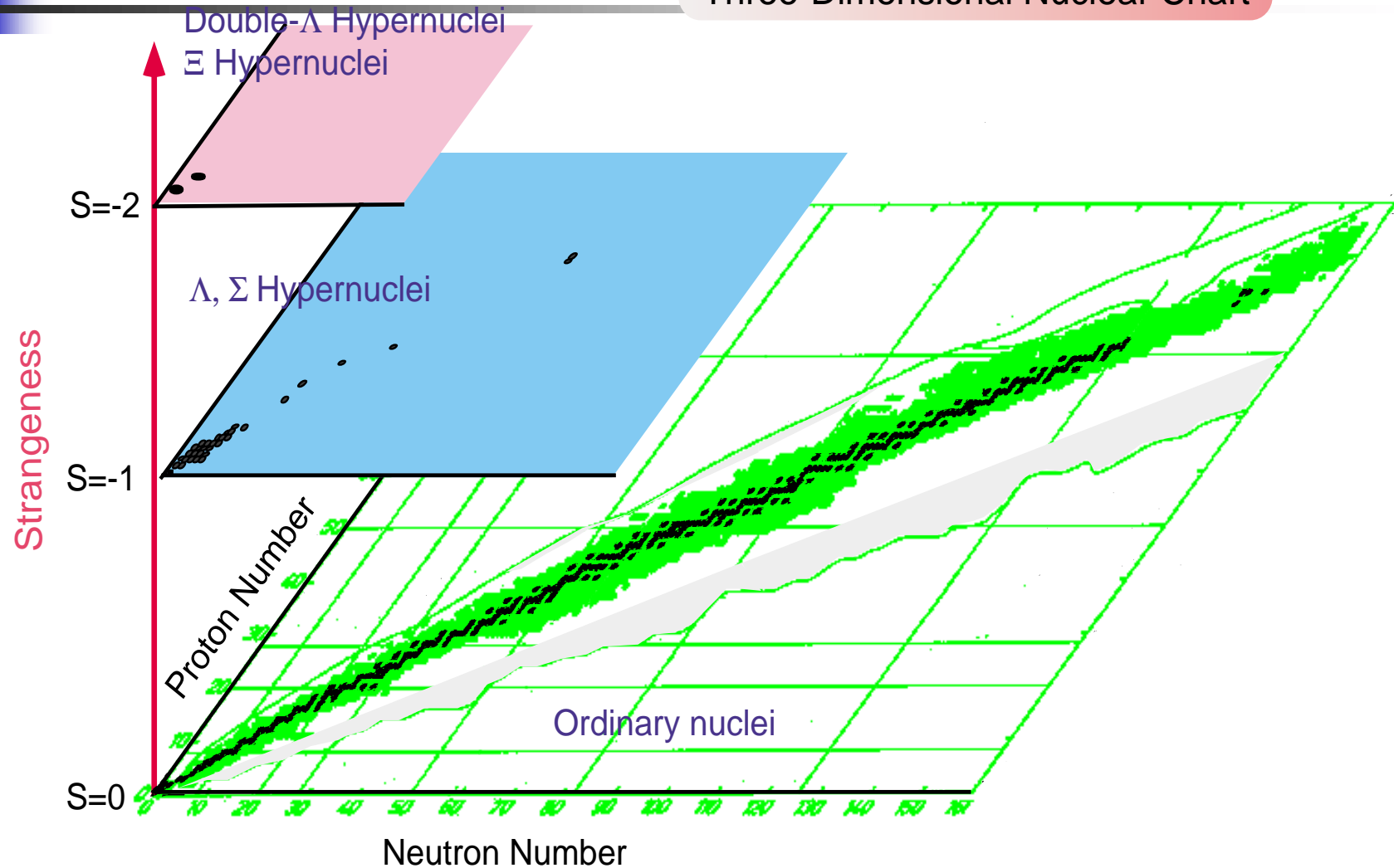
Baryon Many-Body System

Baryon-Baryon Interactions
Meson Exchange \leftrightarrow Quark/Gluon



Strangeness Nuclear Physics

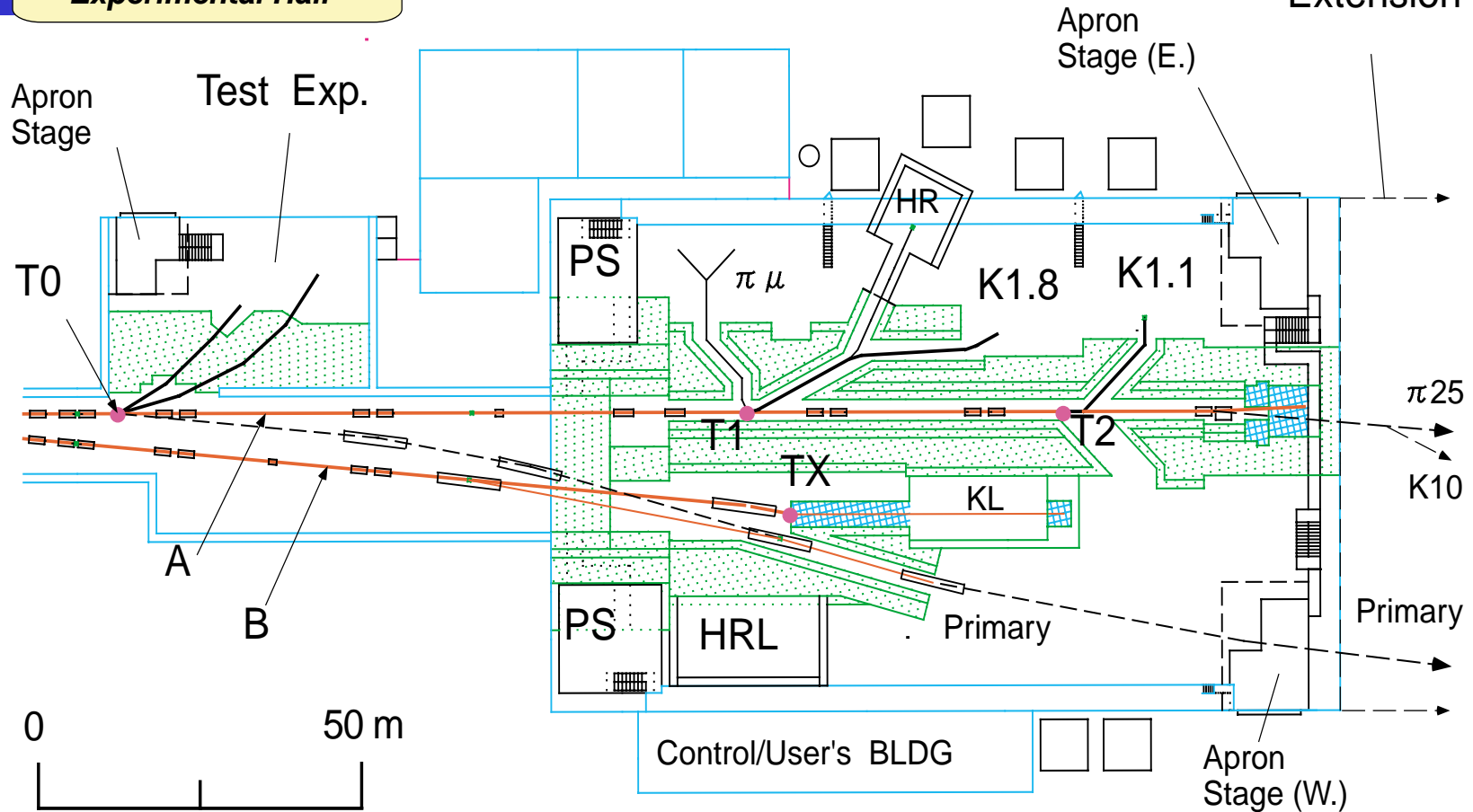
Three-Dimensional Nuclear Chart



Nuclear/Particle Physics Experimental Area

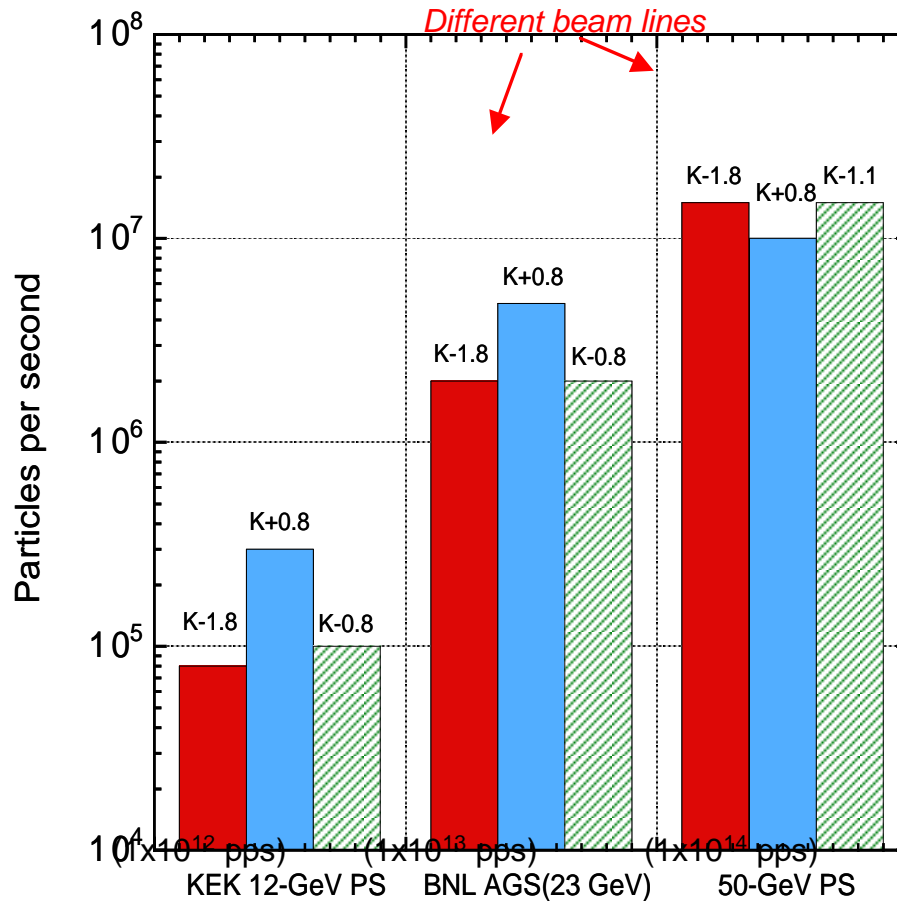
Experimental Hall

Future
Extension



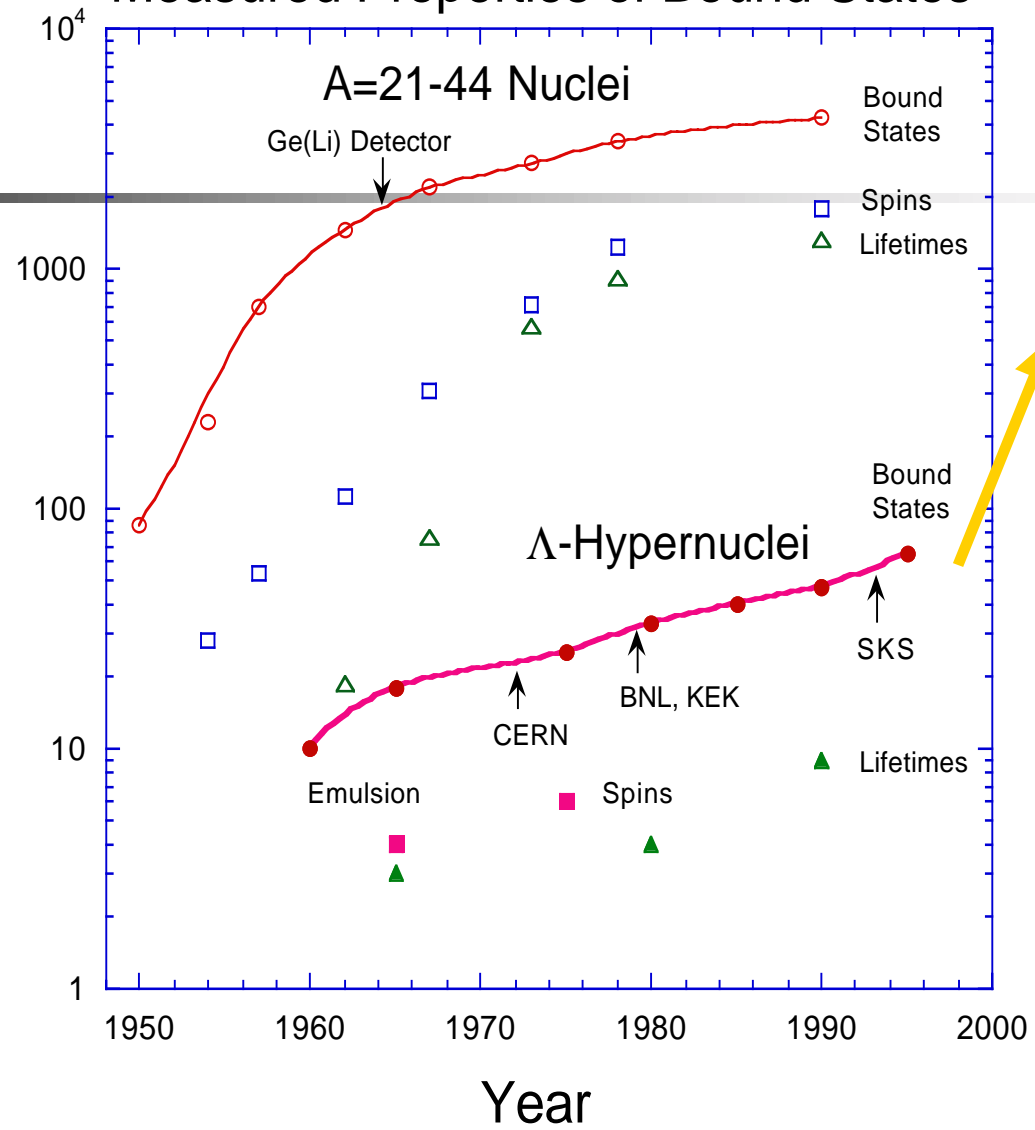
High-Intensity Secondary Beams

Comparison of Beam Intensity



- $K^-(1.8 \text{ GeV}/c)$
(K^-, K^+), $S=-2$
- $K^+(0.8 \text{ GeV}/c)$
 K^+ rare decay
- $K^-(1.1 \text{ GeV}/c)$
(K^-, π^-), $S=-1$

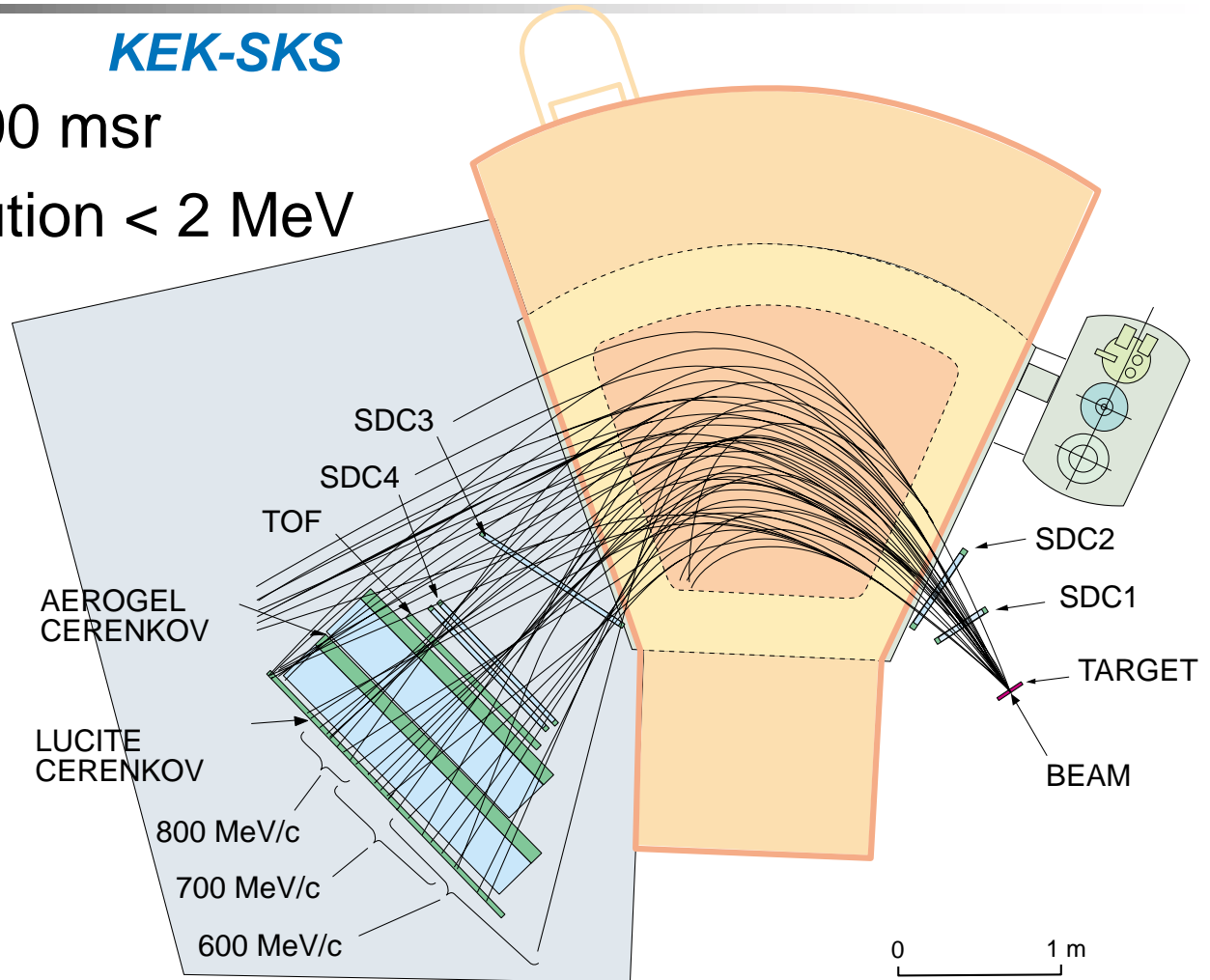
Measured Properties of Bound States



Λ Hypernuclei Spectroscopy with SKS

KEK-SKS

- Large solid angle: 100 msr
- Good Energy Resolution < 2 MeV
- Max. field: 3T
- (π^+, K^+) Reaction at 1.05 GeV/c

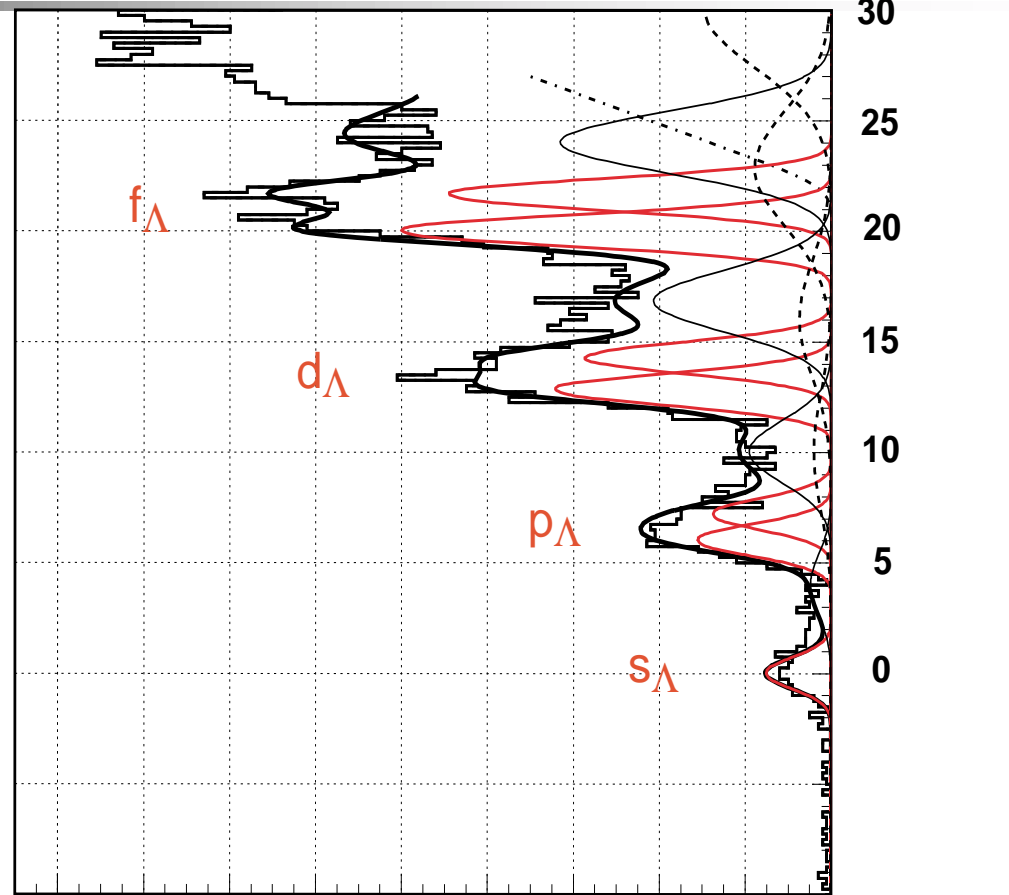
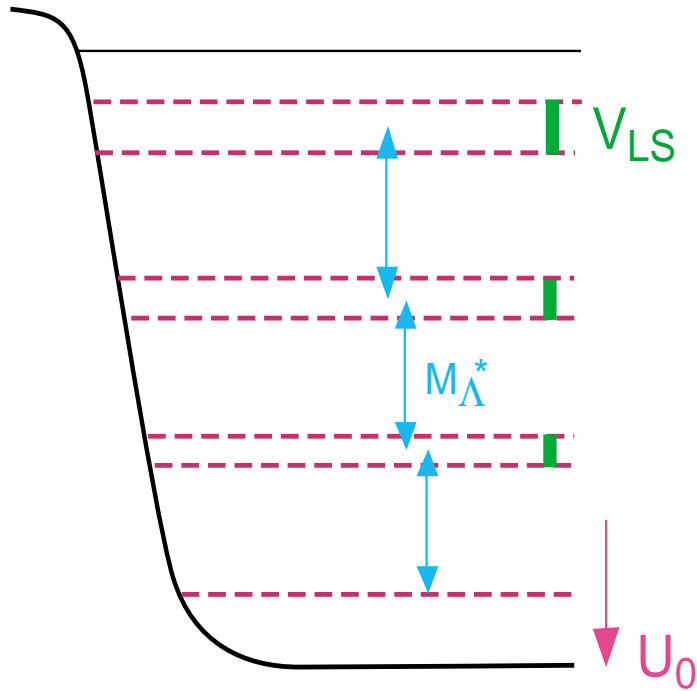


Single-Particle Motion of a Λ in Nuclei

KEK E369

$^{89}\text{Y}(\pi^+, \text{K}^+)$

Excitation Energy (MeV)



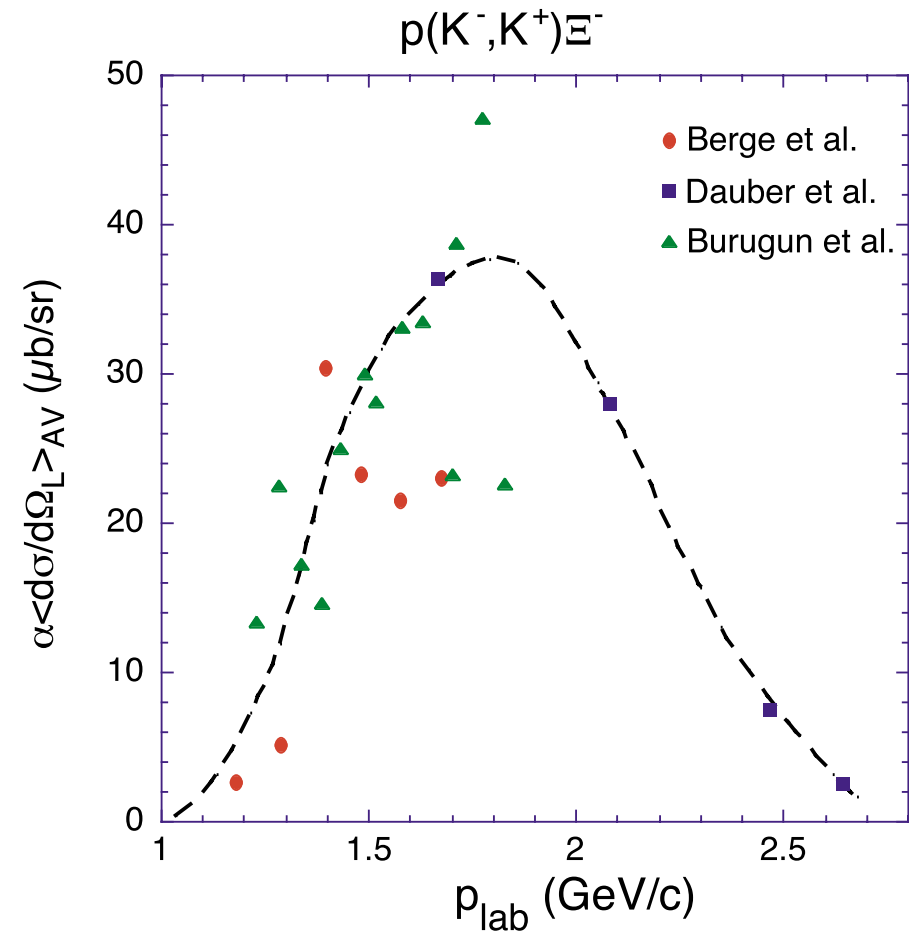


S=-2 Hypernuclear Spectroscopy

- Ξ hypernuclei/ $\Lambda\Lambda$ hypernuclei
 - only three events of $\Lambda\Lambda$ hypernuclei reported
 - Ξ hypernuclear spectroscopy ?
 - a mixed states of Ξ , $\Lambda\Lambda$, and H states ?
 - K. Ikeda et al., Prog. Theor. Phys. 91 (1994) 74
- need high intensity beams at 50-GeV PS
 - (K^-, K^+) reaction at 1.8 GeV/c
 - ex. $^{208}\text{Pb}(K^-, K^+)$ with 2 g/cm² thick target
 - ~6 events/MeV/day
- H dibaryon ($ssuudd$, I=J=0)
 - no evidence so far
 - $m_H > 2200$ MeV (still, 30 MeV below $2m_\Lambda$)
- S=-3 Ω^- nuclei, charmed-hypernuclei etc.

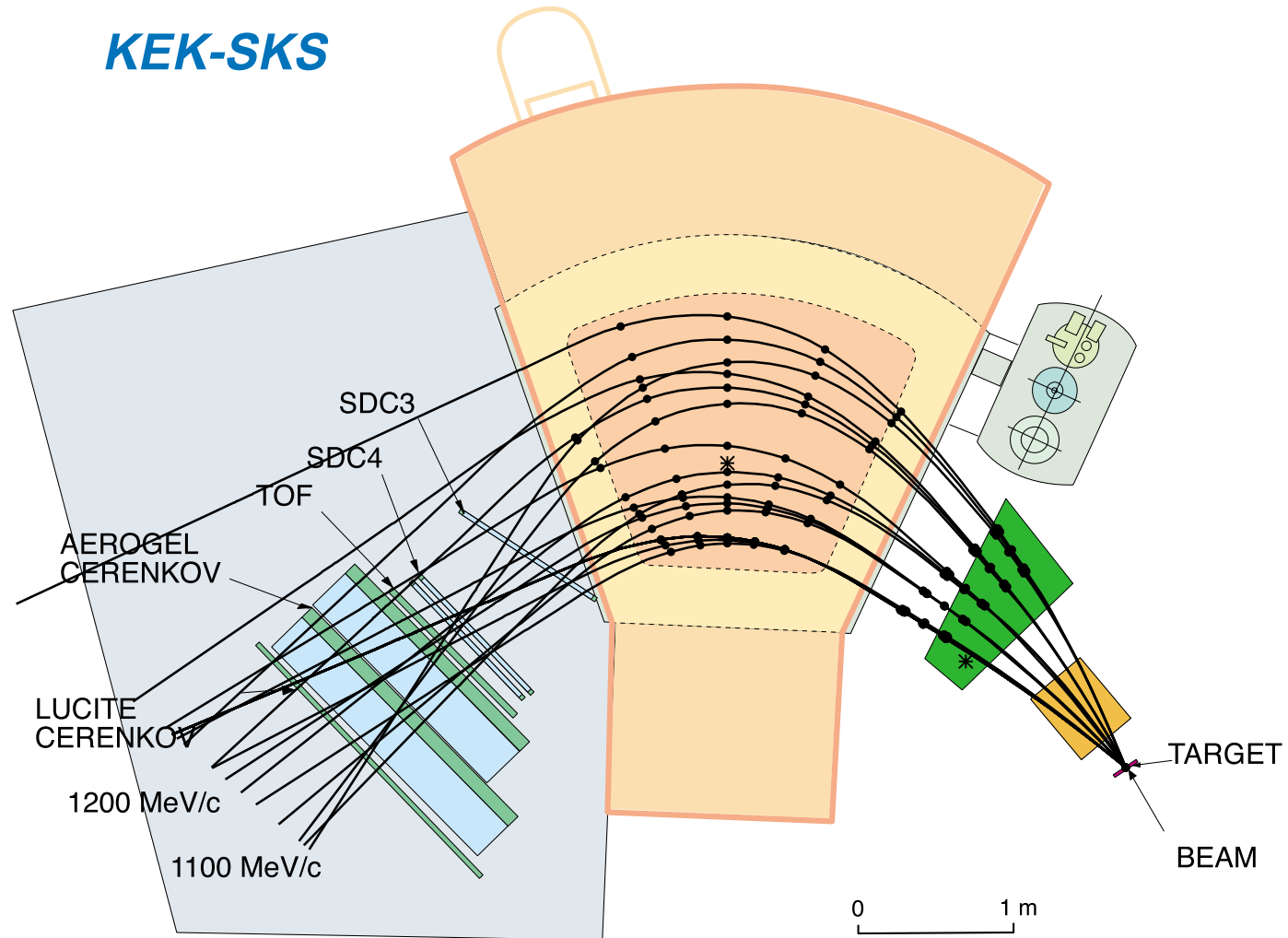
Entrance to the $S=-2$ World

- Doorway Reaction:
 $K^- + p \rightarrow K^+ + \Xi^-$
at 1.8 GeV/c



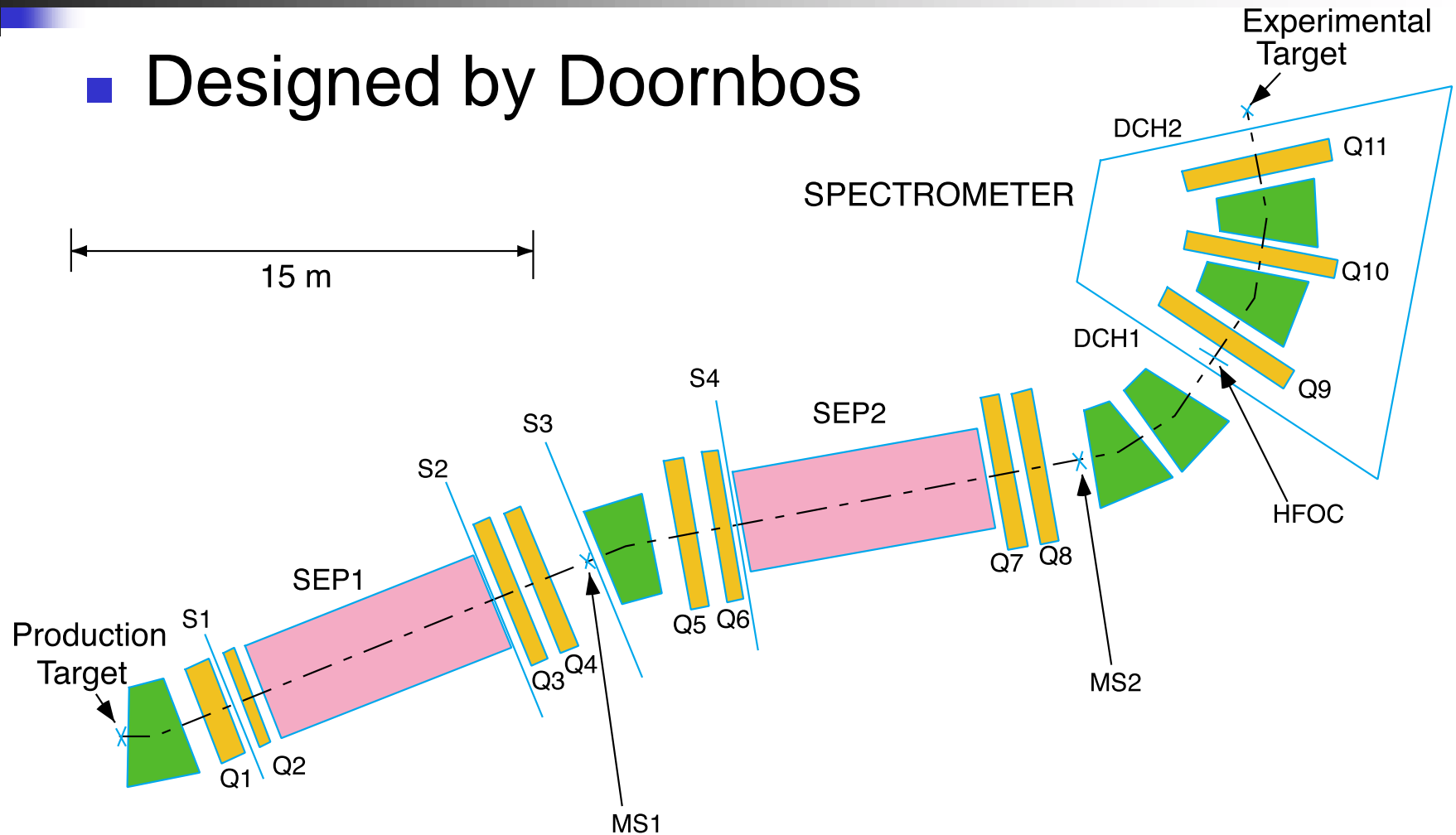
(K^- , K^+) Spectroscopy of Ξ -Hypernuclei

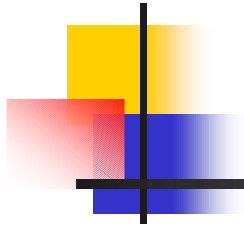
KEK-SKS



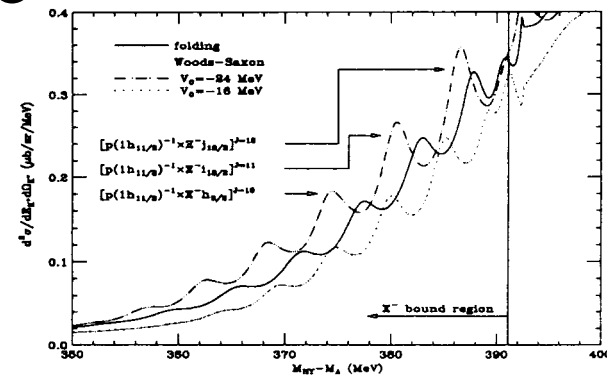
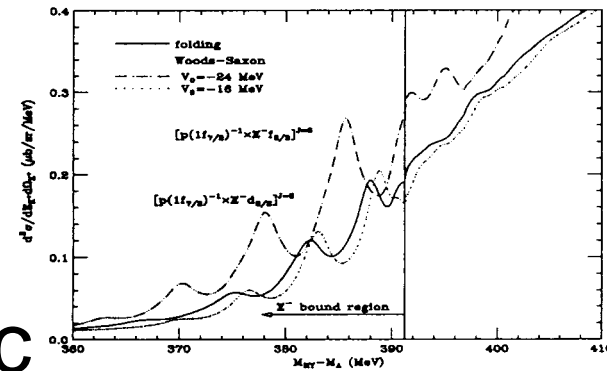
K1.8 Beam Line for JHF

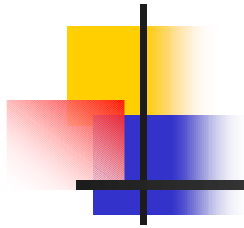
- Designed by Doornbos



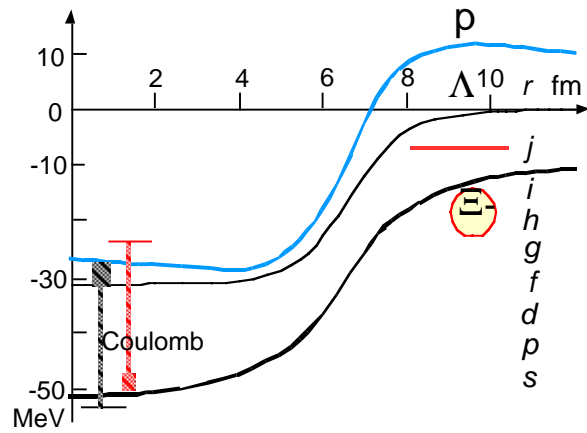


- Coulomb-Assisted bound states
- Large momentum transfer ~ 500 MeV/c
- ~ 6 events/MeV/day

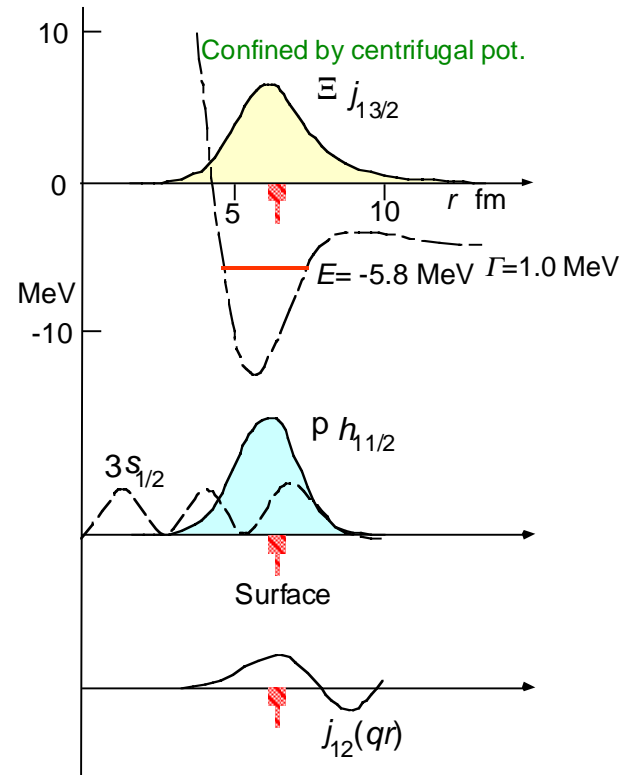




Potential

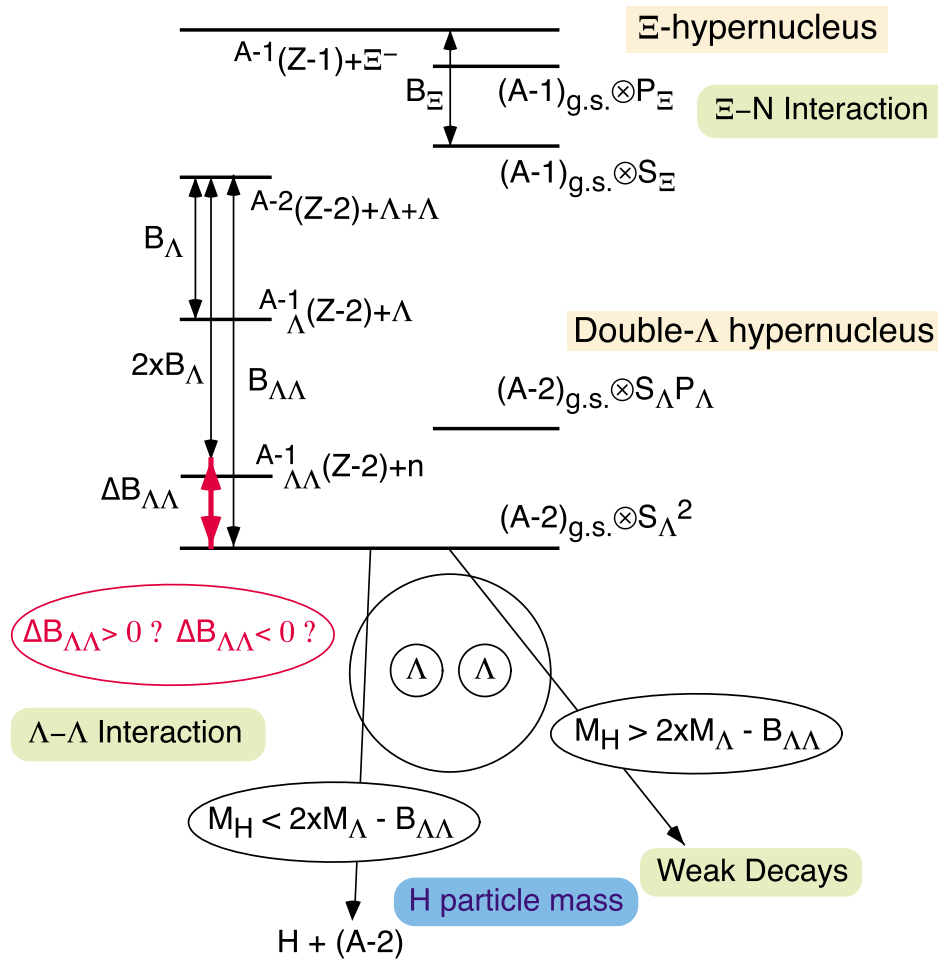


$r^2\rho(r)$

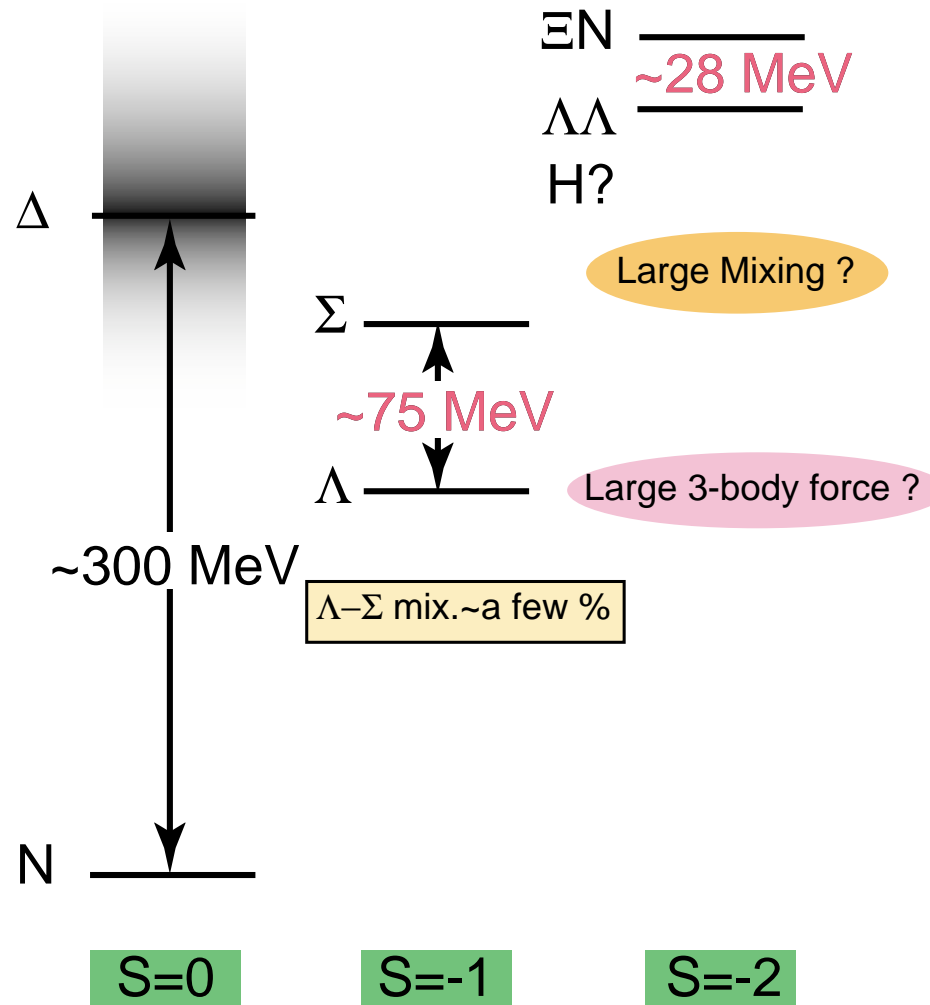


S=-2 Systems

Energy Spectrum of S=-2 systems



Particle Mixing



High-Resolution Spectroscopy of Λ Hypernuclei

- SKS at KEK: 1.5 MeV

Competition


- TJlab: $(e, e'K^+)$ $\Delta E < 0.7$ MeV

- DAFNE: (Stopped K^- , π^-)

FINUDA $\Delta E \sim 0.5$ MeV

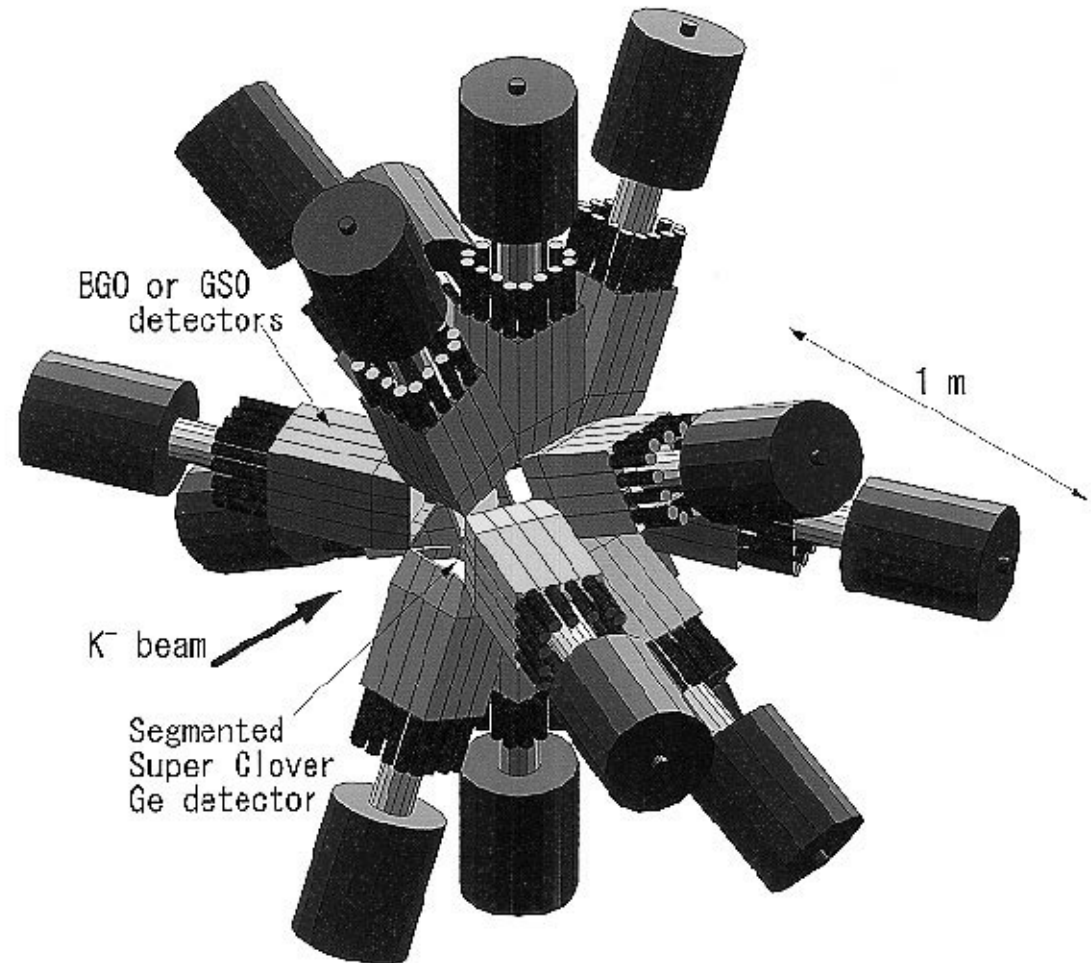
- KEK-BNL: $(\pi^+, K^+)\gamma$, $(K^-, \pi^-)\gamma$

HyperBall $\Delta E \sim 2$ keV

-  50-GeV PS

Hyperball Detector

- 14 sets
- 40% of 4π
- PPE: 12% at 1 MeV





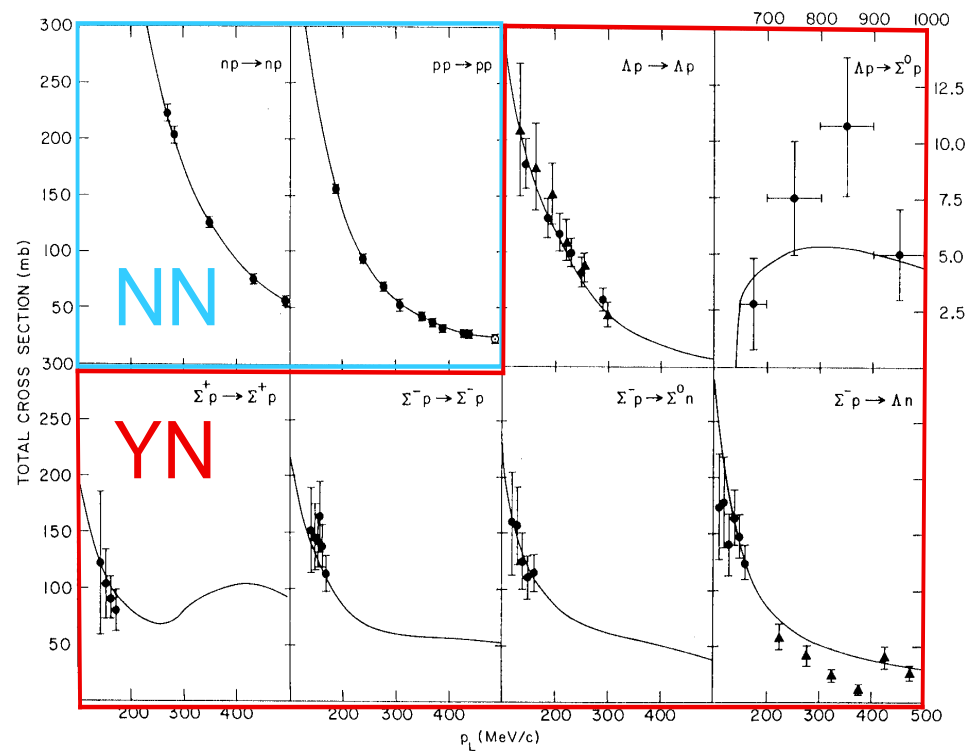
Other measurements

- Heavy Λ -hypernuclei: $^{208}_{\Lambda}\text{Pb}$
 - $E1(p_{\Lambda} \rightarrow s_{\Lambda})$
- Structure change: “glue”-like role of Λ
- B(M1) measurement
 - γ -weak coincidence method
- γ 's from Double- Λ Hypernuclei
- γ 's from Neutron-Rich Λ -hypernuclei

Hyperon-Nucleon Scattering

- Ξ^-p elastic scattering and $\Xi^-p \rightarrow \Lambda\Lambda$ reaction
- Asymmetry in Λp and Σ^+p elastic scattering

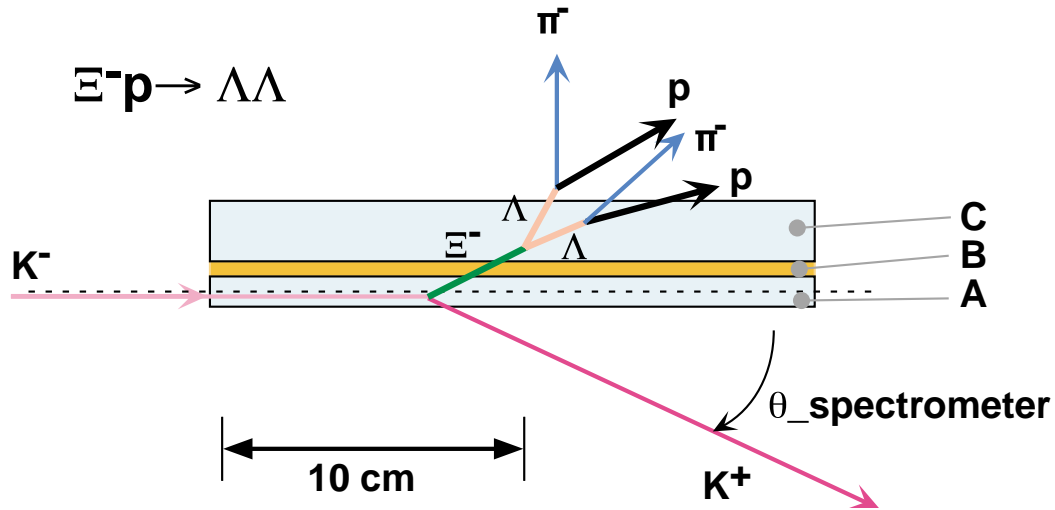
$\Lambda^+p, \Sigma^+p, \Sigma^-p$ and Ξ^-p scattering



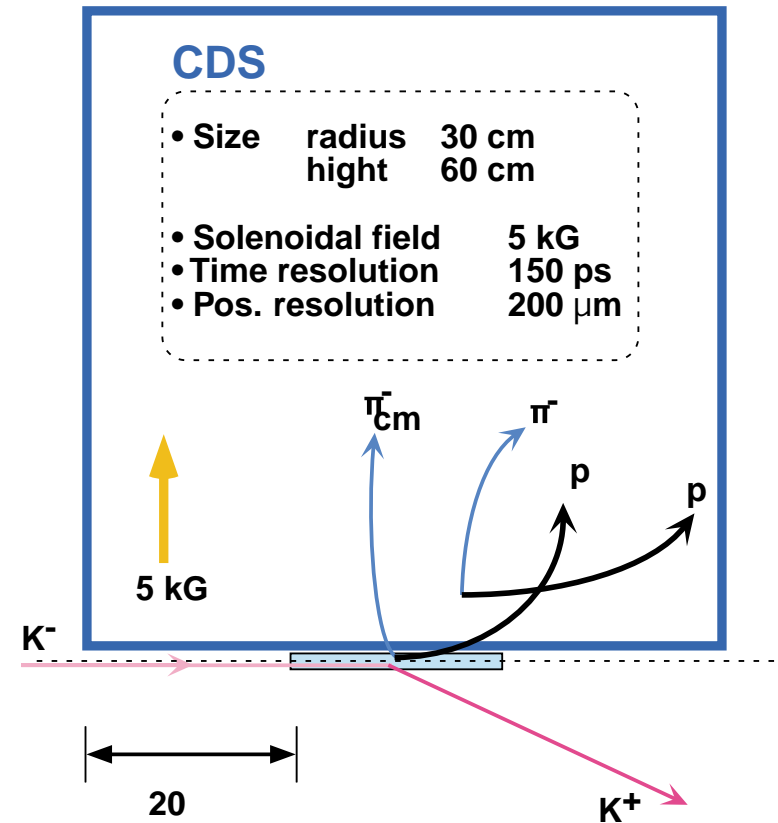
from Dover & Feshbach Ann.Phys.198(90)321

Need high quality data with high statistics

$\Xi^- p \rightarrow \Lambda \Lambda$ reaction



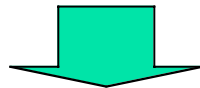
In 100 days:
 3650 events of $\Xi^- p \rightarrow \Xi^- p$
 850 events of $\Xi^- p \rightarrow \Lambda \Lambda$





Summary

- A lot of exciting experiments on Strangeness Nuclear Physics are waiting for the 50-GeV PS
 - Spectroscopy of $S=-2$ Systems: Ξ - and $\Lambda\Lambda$ -Hypernuclei
 - High-resolution γ -ray spectroscopy
 - Hyperon-Proton scattering, etc.



- The 50-GeV PS will open a New world of Hadron Many-Body Physics