RETROSPECTIVE

Kaonic Nuclear States Search with FOPI and DISTO

Ken Suzuki

Workshop dedicated to the memory of Paul Kienle

LNF 21.06.2013

Tribute in memory of Prof. Dr. Paul Kienle†

Eur. Phys. J. A (2012) **48**: 183
DOI 10.1140/epja/i2012-12183-5

THE EUROPEAN PHYSICAL JOURNAL A

Letter

Formation of the $S = -1$ resonance $X(2265)$ in the reaction $pp \to X + K^+$ at 2.50 and 2.85 GeV

P. Kienle[1,2], M. Maggiora[3], K. Suzuki[2,a], T. Yamazaki[4,5], M. Alexeev[3,14], F. Balestra[3], Y. Bedfer[6], R. Bertini[3,6], L.C. Bland[7], A. Brenschede[8], F. Brochard[6], M.P. Bussa[3], M. Chiosso[3], Seonho Choi[7], M.L. Colantoni[3], R. Dressler[13], M. Dzemidzic[7], J.-Cl. Faivre[6], A. Ferrero[3], L. Ferrero[3], J. Foryciarz[10,11], I. Fröhlich[8], V. Frolov[9], R. Garfagnini[3], A. Grasso[3], S. Heinz[3,6], W.W. Jacobs[7], W. Kühn[8], A. Maggiora[3], D. Panzieri[12], H.-W. Pfaff[8], G. Pontecorvo[3,9], A. Popov[9], J. Ritman[8], P. Salabura[10], V. Tchalyshev[9], F. Tosello[3], S.E. Vigdor[7], and G. Zosi[3]

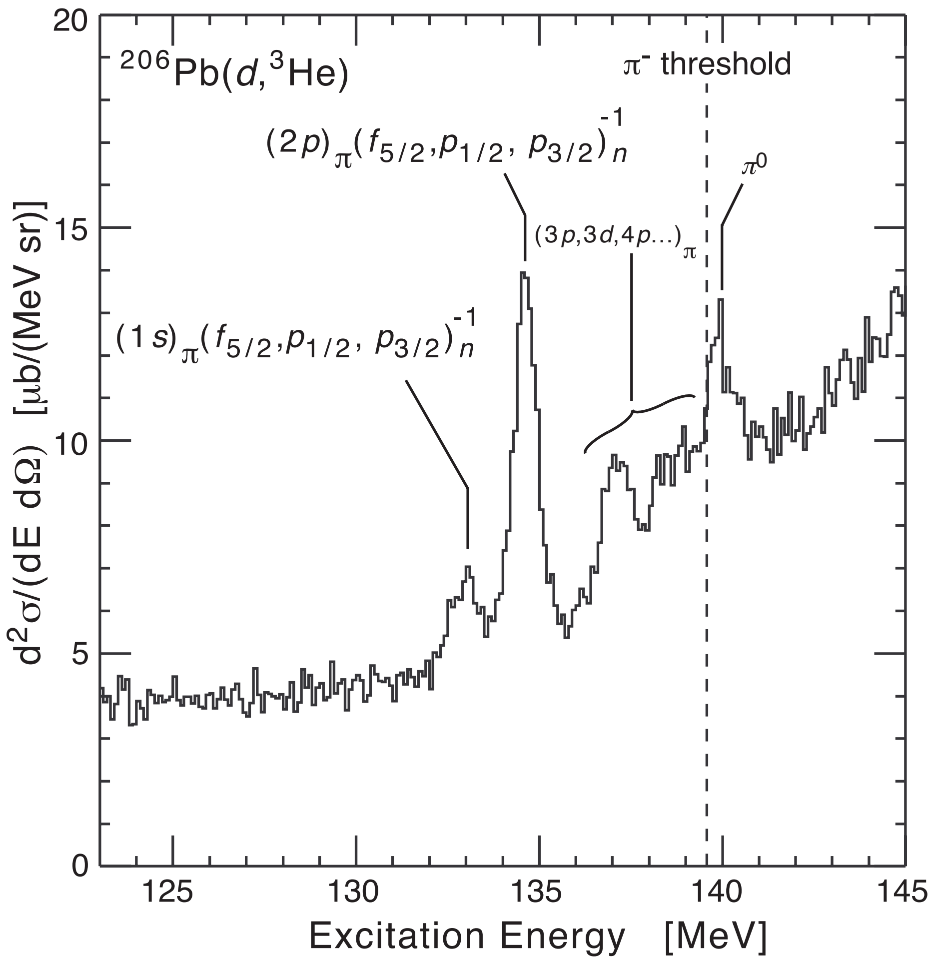
20.11.1998

S160′ [^{206}Pb(d,^{3}He)^{205}Pb⊗π] End of Run Party

VOLUME 88, NUMBER 12 PHYSICAL REVIEW LETTERS 25 MARCH 2002

Deeply Bound 1*s* and 2*p* Pionic States in ^{205}Pb and Determination of the *s*-Wave Part of the Pion-Nucleus Interaction

H. Geissel,[1] H. Gilg,[2] A. Gillitzer,[3] R. S. Hayano,[4] S. Hirenzaki,[5] K. Itahashi,[6] M. Iwasaki,[6] P. Kienle,[2] M. Münch,[2] G. Münzenberg,[1] W. Schott,[2] K. Suzuki,[4] D. Tomono,[6] H. Weick,[1] T. Yamazaki,[7] and T. Yoneyama[6]



17.05.2001

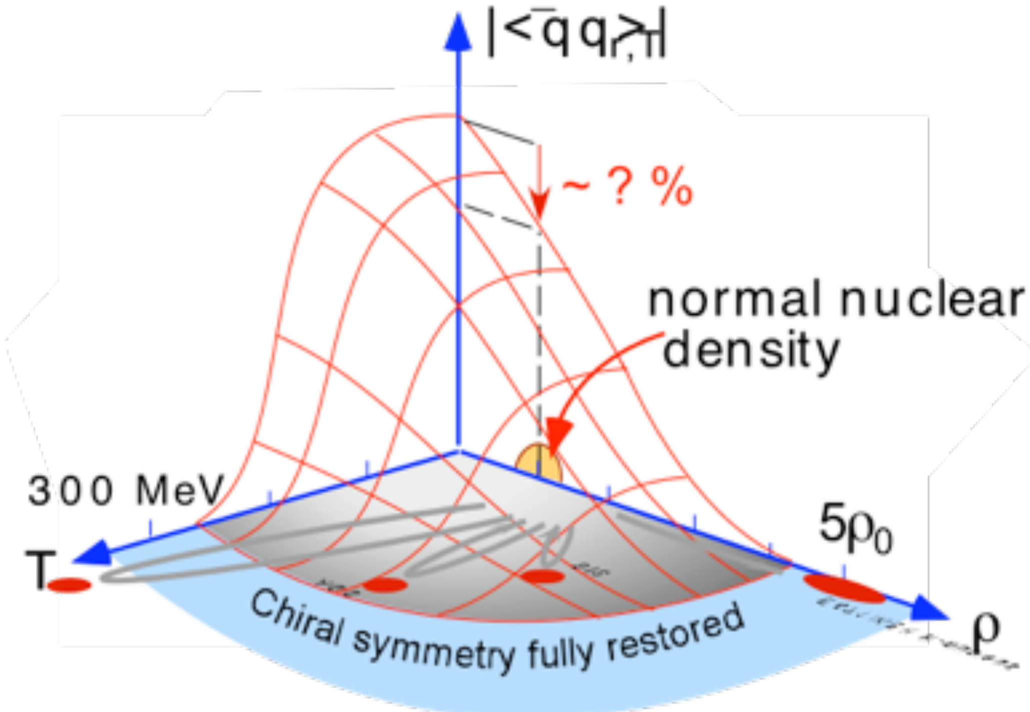
S236 [$^{116,120,124}Sn(d,^{3}He)^{115,119,123}Pb\otimes\pi$] End of Run Party

VOLUME 92, NUMBER 7 PHYSICAL REVIEW LETTERS week ending 20 FEBRUARY 2004

Precision Spectroscopy of Pionic 1s States of Sn Nuclei and Evidence for Partial Restoration of Chiral Symmetry in the Nuclear Medium

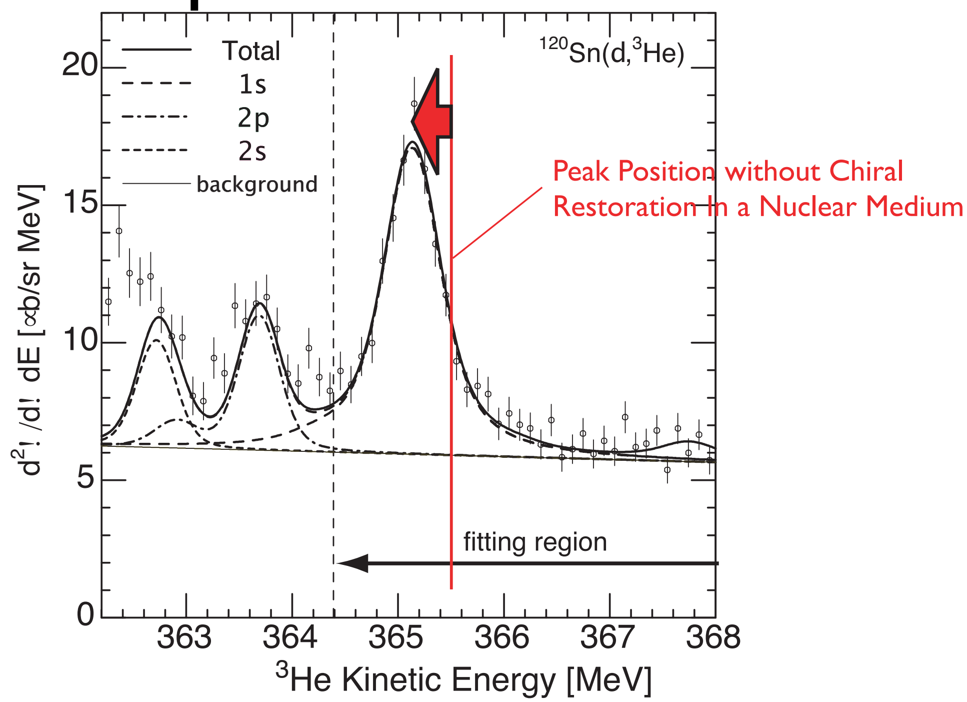
K. Suzuki,[1] M. Fujita,[2] H. Geissel,[3] H. Gilg,[4] A. Gillitzer,[5] R. S. Hayano,[1] S. Hirenzaki,[2] K. Itahashi,[6] M. Iwasaki,[6] P. Kienle,[4,7] M. Matos,[3] G. Münzenberg,[3] T. Ohtsubo,[8] M. Sato,[9] M. Shindo,[1] T. Suzuki,[1] H. Weick,[3] M. Winkler,[3] T. Yamazaki,[10] and T. Yoneyama[9]

Order parameter of Chiral symmetry <q̄q>



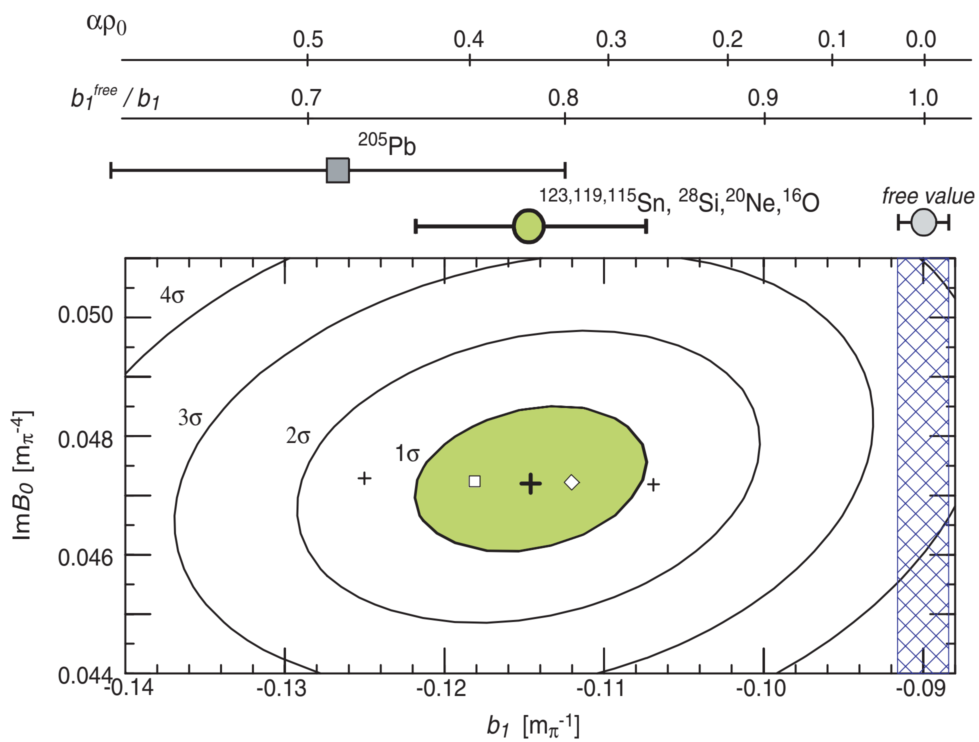
K. Suzuki et al. PRL92(2003)

pionic Sn states



π-Nucleus interaction/
π-N interaction⇒Medium effect

Still one of the very unique quantitative data on a partial restoration of chiral symmetry at finite density



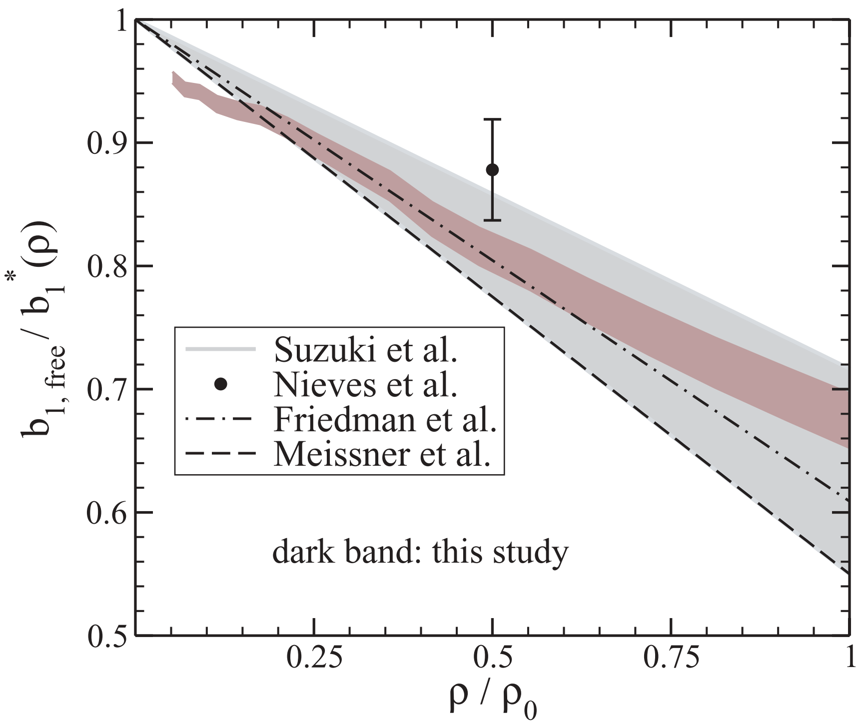


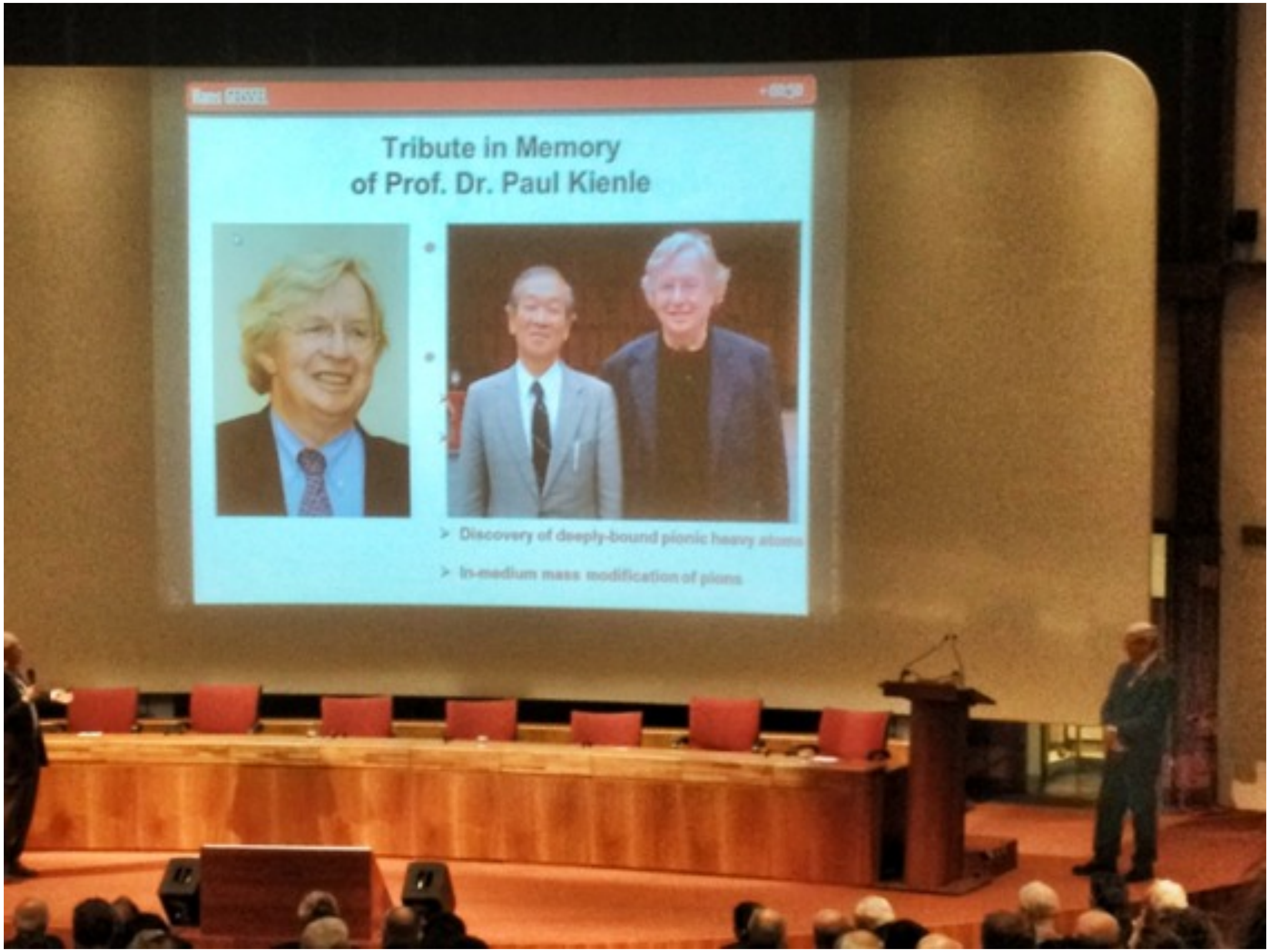
FIG. 17. (Color online) In-medium isovector $b_1^*(\rho)$ compared to the vacuum isovector term $b_{1,\text{free}}$. The gray band from Suzuki *et al.* [26] is from a phenomenological fit as is the point from Nieves *et al.* [22]. Also shown are chiral calculations from Meißner *et al.* [25] and Friedman *et al.* [71] (including those of Weise [13]).

107 citations as of May 2013

M. Döring and E. Oset, PRC 77 (2008) 024602

24.06.2002

On Hongo Campus, Univ. of Tokyo



04.06.2013

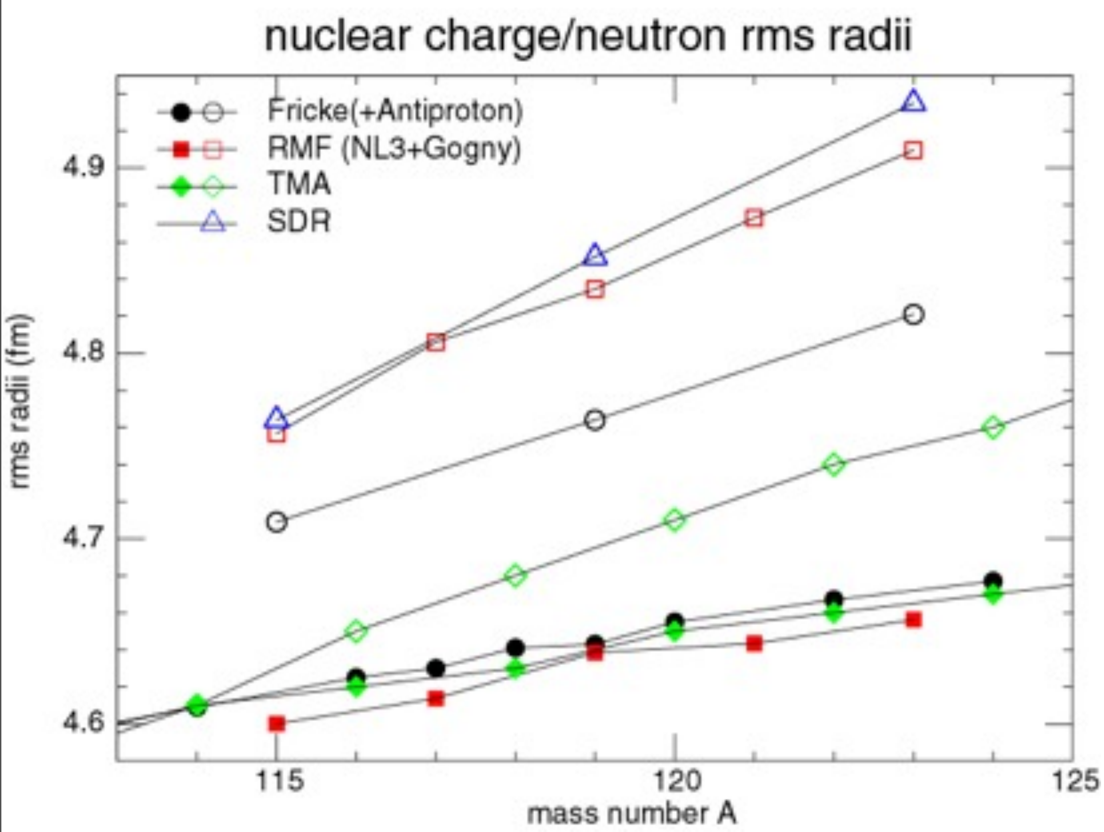
Hans Geissel at his plenary talk at INPC2013 Firenze

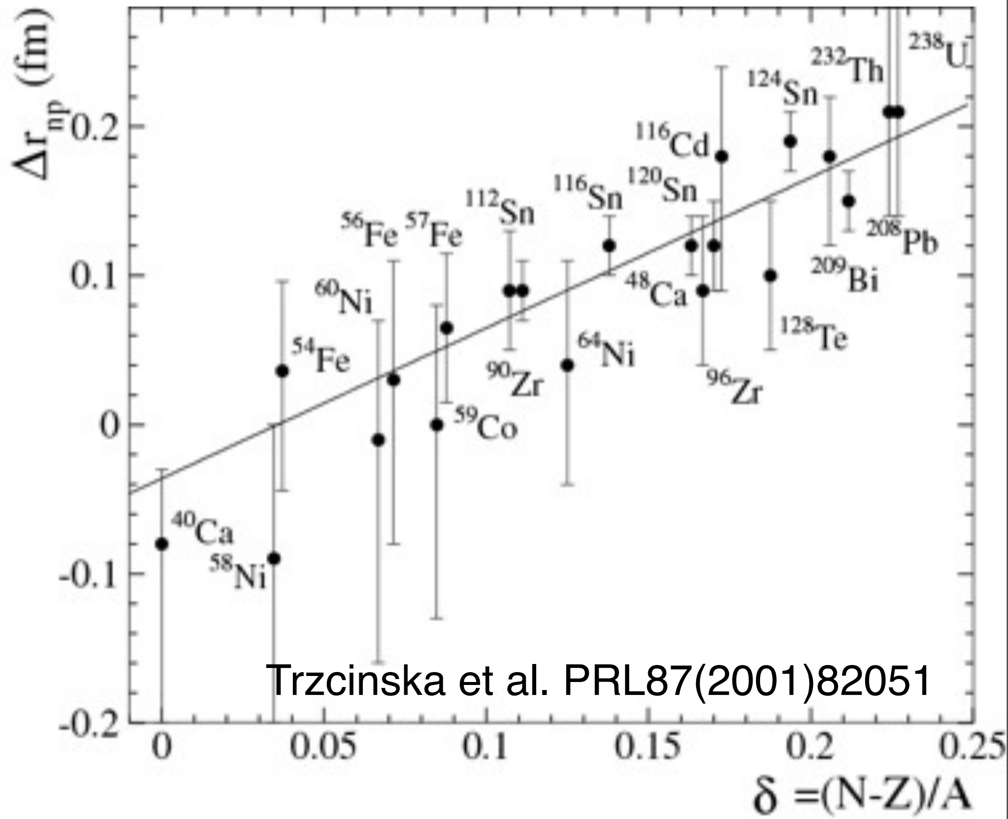
24.06.2002

On Hongo Campus, Univ. of Tokyo

24.06.2002
In Ken‘s Office at the University of Tokyo

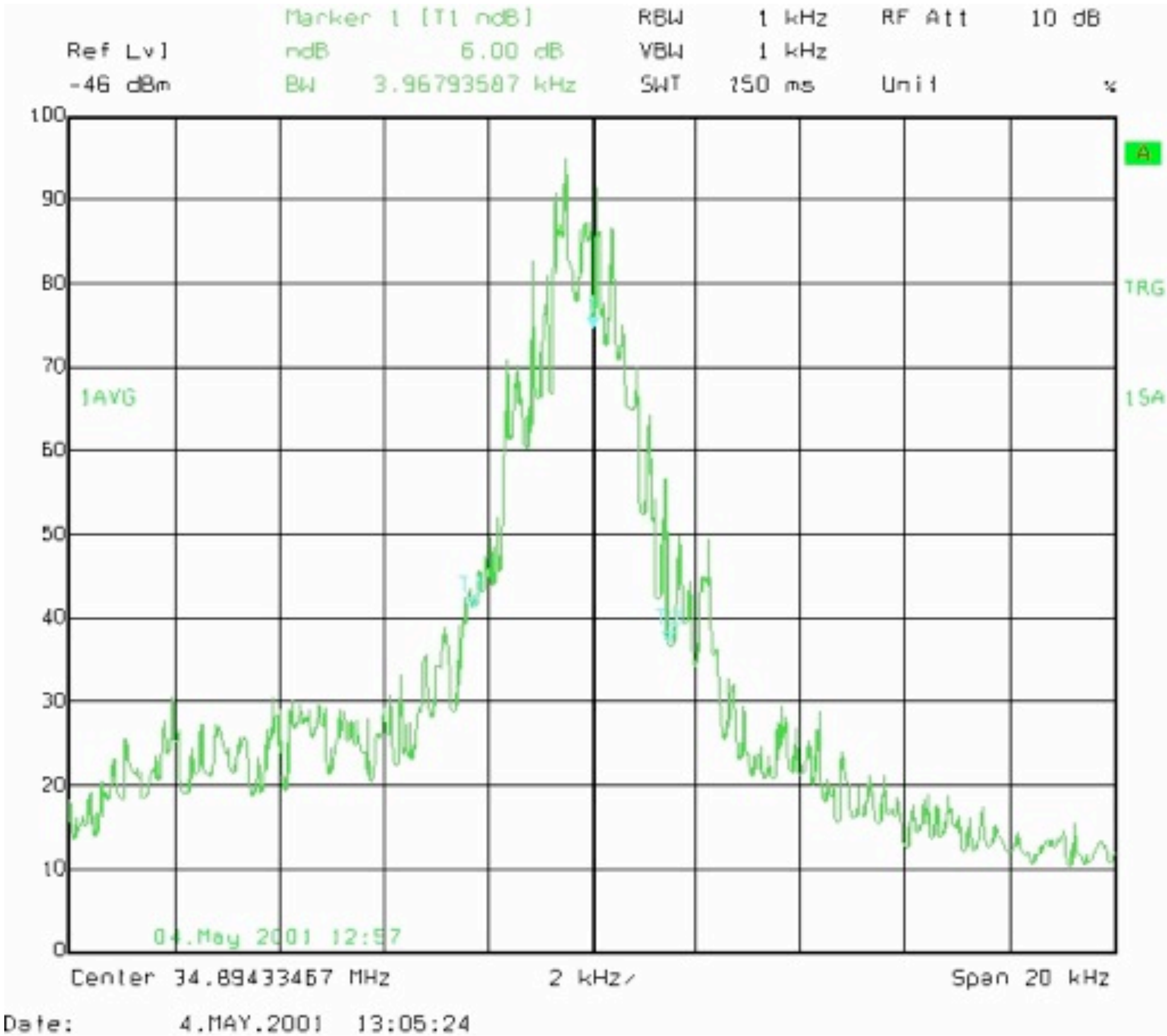
Neutron rms Radii





Neutron Radii Meas. At LEAR, CERN
Using Anti proton as a probe

Schottky Measurement



AIC (Antiproton-Ion-Collider)

ÖAW
Österreichische Akademie der Wissenschaften

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Nuclear Instruments and Methods in Physics Research B 214 (2004) 191–195

NIM B
Beam Interactions with Materials & Atoms

www.elsevier.com/locate/nimb

Medium energy antiproton absorption, a tool to study neutron halo nuclei

P. Kienle *

Fakultät für Physik, Technische Universität München, James-Franck-Strasse, 85748 Garching, Germany
Institut für Mittelenergiephysik, 1090 Wien, Austria

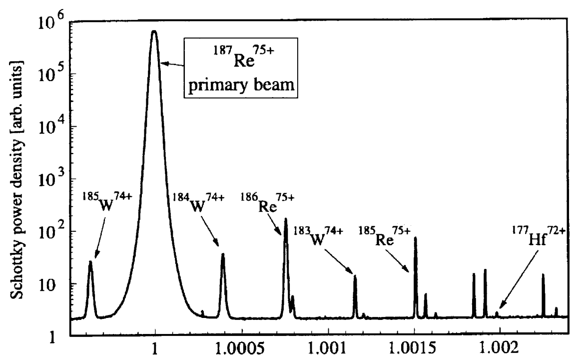


Fig. 4. Schottky noise power spectrum as function of the relative revolution frequency, normalized to the revolution frequency of a $^{187}Re^{75b}$ primary beam coasting in the ESR for 200 s through an argon gas jet target with $3 \cdot 10^{12}$ argon atoms/cm^2. Note the narrow side lines with small numbers ofi ons, which can be assigned to projectile fragments produced in the intersecting argon gas jet target. By replacing the argon target with antiprotons at 5 MeV in a small collider ring, all absorption products could be detected in the Schottky spectrum.

2003 March Dissertation

~~2003 April California~~

2003 April München

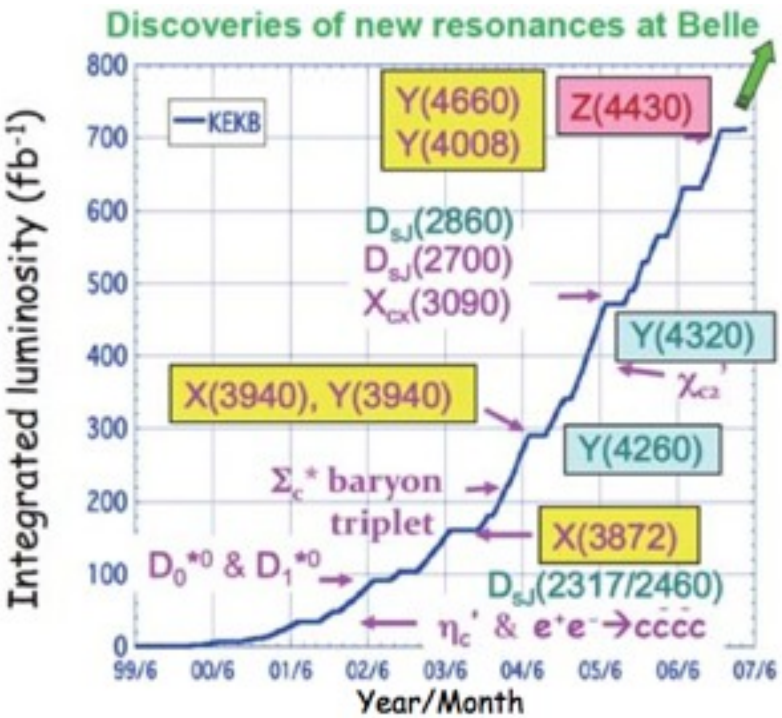
2003

was the year of exotic hadrons:
„new form of hadron“

Winter 2003

Belle reported X(3872)

Non-CQM-like particles found in charmonium spectroscopy, collectively called „*XYZ*-state“



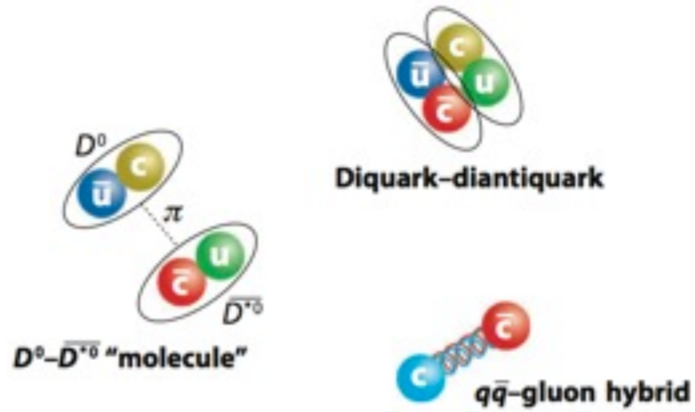


Table 1 Properties of the candidate *XYZ* mesons

State	M (MeV)	Γ (MeV)	J^{PC}	Decay modes	Production modes	Reference(s)
$Y_s(2175)$	2175 ± 8	58 ± 26	1^{--}	$\phi f_0(980)$	e^+e^- (ISR), J/ψ decay	127, 128
$X(3872)$	3871.4 ± 0.6	<2.3	1^{++}	$\pi^+\pi^- J/\psi$, $\gamma J/\psi$	$B \to K X(3872)$, $p\bar{p}$	63–66
$X(3875)$	3875.5 ± 1.5	$3.0^{+2.1}_{-1.7}$		$D^0 \bar{D}^0 \pi^0$	$B \to K X(3875)$	81, 82
$Z(3940)$	3929 ± 5	29 ± 10	2^{++}	$D\bar{D}$	$\gamma\gamma$	89
$X(3940)$	3942 ± 9	37 ± 17	J^{P+}	$D\bar{D}^*$	$e^+e^- \to J/\psi X(3940)$	87, 92
$Y(3940)$	3943 ± 17	87 ± 34	J^{P+}	$\omega J/\psi$	$B \to K Y(3940)$	88, 93
$Y(4008)$	4008^{+82}_{-49}	226^{+97}_{-80}	1^{--}	$\pi^+\pi^- J/\psi$	e^+e^- (ISR)	101
$X(4160)$	4156 ± 29	139^{+113}_{-65}	J^{P+}	$D^* \bar{D}^*$	$e^+e^- \to J/\psi X(4160)$	92
$Y(4260)$	4264 ± 12	83 ± 22	1^{--}	$\pi^+\pi^- J/\psi$	e^+e^- (ISR)	96, 100, 101
$Y(4350)$	4361 ± 13	74 ± 18	1^{--}	$\pi^+\pi^- \psi'$	e^+e^- (ISR)	102, 103
$Z(4430)$	4433 ± 5	45^{+35}_{-18}	?	$\pi^\pm \psi'$	$B \to K Z^\pm(4430)$	114
$Y(4660)$	4664 ± 12	48 ± 15	1^{--}	$\pi^+\pi^- \psi'$	e^+e^- (ISR)	103
Y_b	$\sim 10,870$	?	1^{--}	$\pi^+\pi^- \Upsilon(nS)$	e^+e^-	125

„Hadron Physics at Belle“,
T. Iijima, AIP Conf. Proc. 1388 (2011) 156.

„The Exotic XYZ Charmonium-Like Mesons“,
S. Godfrey and S. L. Olsen, Ann. Rev. Nucl. Part. Sci. 58 (2008) 51

Most cited Belle publication

X(3872) - 2003

CP Violation - 2001

1. Title: Observation of a narrow charmoniumlike state in exclusive B+/--> K+/-pi(+)pi(-)J/psi decays
Author(s): Choi, SK; Olsen, SL; Abe, K; et al.
Group Author(s): Belle Collaboration
Source: PHYSICAL REVIEW LETTERS Volume: 91 Issue: 26 Article Number: 262001 DOI: 10.1103/PhysRevLett.91.262001 Published: DEC 31 2003

2. Title: Observation of large CP violation in the neutral B meson system
Author(s): Abe, K; Abe, K; Abe, R; et al.
Group Author(s): Belle Collaborat
Source: PHYSICAL REVIEW LETTERS Volume: 87 Issue: 9 Article Number: 091802 DOI: 10.1103/PhysRevLett.87.091802 Published: AUG 27 2001

3. Title: Observation of double c(c)over-bar production in e(+)e(-) annihilation at root s approximate to 10.6 GeV
Author(s): Abe, K; Abe, K; Abe, R; et al.
Group Author(s): Belle Collaboration
Source: PHYSICAL REVIEW LETTERS Volume: 89 Issue: 14 Article Number: 142001 DOI: 10.1103/PhysRevLett.89.142001 Published: SEP 30 2002

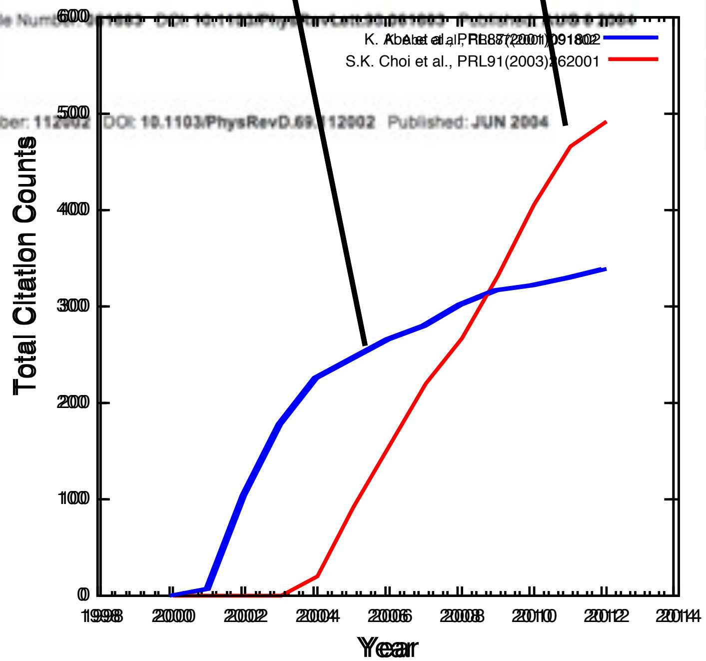
4. Title: Improved measurement of mixing-induced CP violation in the neutral B meson system
Author(s): Abe, K; Abe, K; Abe, T; et al.
Group Author(s): Belle Collaboration
Source: PHYSICAL REVIEW D Volume: 66 Issue: 7 Article Number: 071102 DOI: 10.1103/PhysRevD.66.071102 Published: OCT 1 2002

5. Title: Observation of the DsJ(2317) and DsJ(2457) in B decays
Author(s): Krokovny, P; Abe, K; Abe, K; et al.
Group Author(s): Belle Collaboration
Source: PHYSICAL REVIEW LETTERS Volume: 91 Issue: 26 Article Number: 262002 DOI: 10.1103/PhysRevLett.91.262002 Published: DEC 31 2003

6. Title: Inclusive measurement of the photon energy spectrum in b -> s gamma decays
Author(s): Koppenburg, P; Abe, K; Abe, K; et al.
Group Author(s): Belle Collaboration
Source: PHYSICAL REVIEW LETTERS Volume: 93 Issue: 6 Article Number: ...

7. Title: Study of B(-)-> D(**0)pi(-)(D(**0)-> D(*)+)pi(-)) decays
Author(s): Abe, K; Abe, K; Abe, T; et al.
Group Author(s): Belle Collaboration
Source: PHYSICAL REVIEW D Volume: 69 Issue: 11 Article Number: 112002 DOI: 10.1103/PhysRevD.69.112002 Published: JUN 2004

2008	2009	2010	2011	2012	Total	Average Citations per Year
1008	1101	1054	790	440	8886	592.40
47	65	74	60	26	492	49.20
22	15	5	8	9	339	28.25
22	23	14	19	6	218	19.82
6	12	2	1	4	213	19.36
14	16	12	10	6	178	17.80
28	14	14	11	0	166	18.44
18	15	5	8	3	154	17.11



Data from Web of Knowledge

Summer 2003

Pentaquark

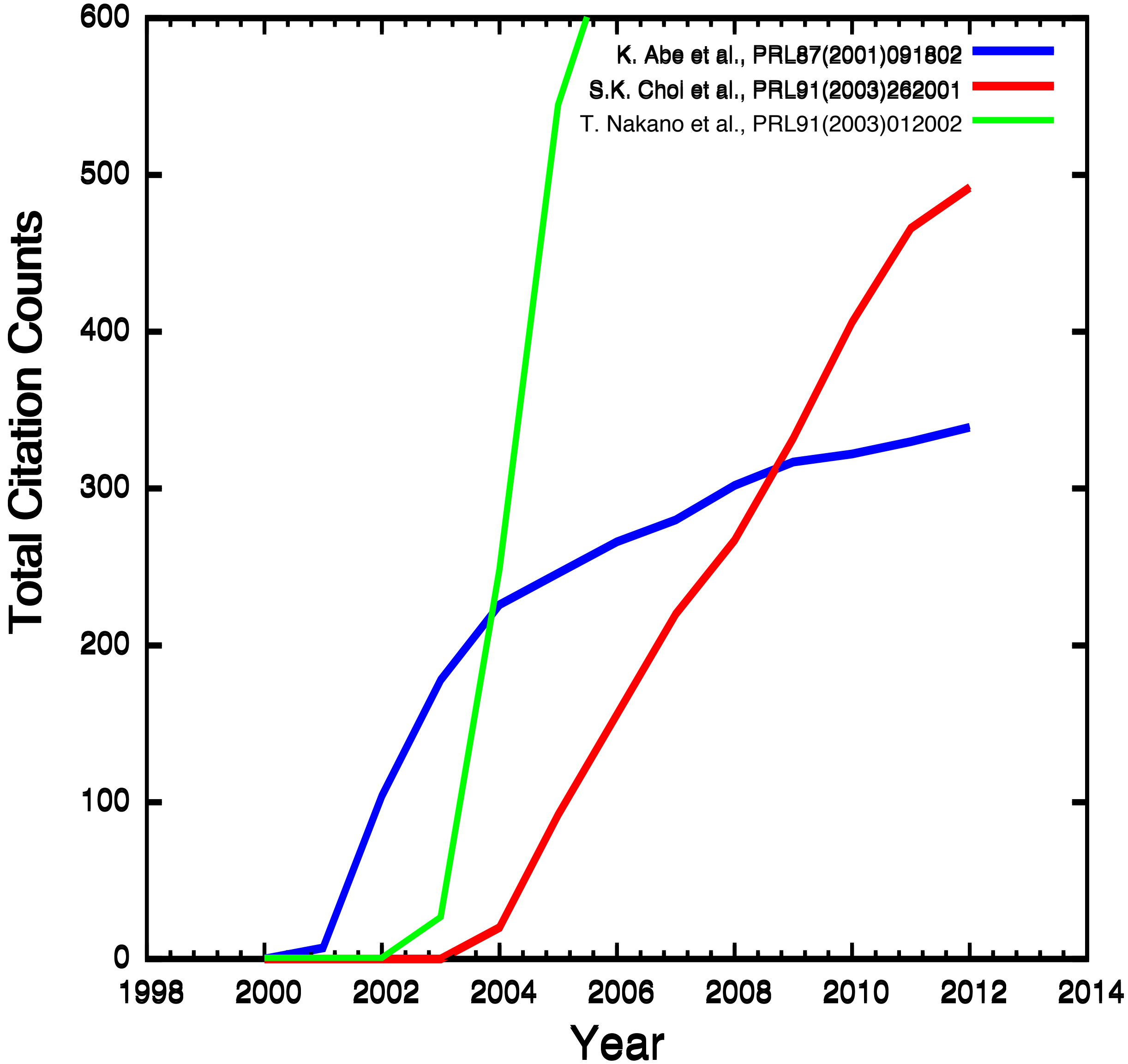
Mini Review in PDG

PENTAQUARKS

Written May 2008 by C.G. Wohl (LBNL).

See pp. 1019–1022 of the 2006 *Review* [1] for the evidence for the $\Theta(1540)$, $\Phi(1860)$, and $\Theta_c(3100)$, and for the early unsuccessful attempts to confirm them. The table below lists papers published since then giving results of further unsuccessful searches. There are experiments at high energies and low; in new reactions and old; there are experiments—some by the same groups that claimed the original discoveries—with orders-of-

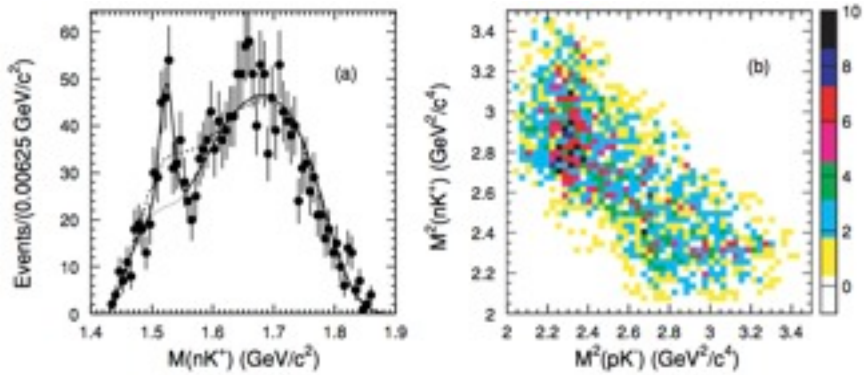
There are two or three recent experiments that find weak evidence for signals near the nominal masses, but there is simply no point in tabulating them in view of the overwhelming evidence that the claimed pentaquarks do not exist. The only advance in particle physics thought worthy of mention in the American Institute of Physics "Physics News in 2003" was a false alarm. The whole story—the discoveries themselves, the tidal wave of papers by theorists and phenomenologists that followed, and the eventual "undiscovery" —is a curious episode in the history of science.



Data from Web of Knowledge

- LEPS group confirmed their 2003 data with higher statistics („Evidence for the Θ^+ in the $\gamma d \to K^+K^- pn$ reaction by detecting K^+K^- pairs“, T. Nakano et al., Phys. Rev. C79 (2009) 025210).

$\gamma n \to K^-\Theta^+ \to K^-K^+n$



- The most recent „dedicated“ Θ^+ search at J-PARC/Japan observes, though still preliminary, no structure („Search for the Θ^+ pentaquark via the $\pi^- p \to K^- X$ reaction at 1.92 GeV/c“, K. Shirotori *et al.*, nucl-ex:1203.3604)

$\pi^- p \to K^- X$ reaction

- only s-channel process contributes
- no strong angular dependence
- sizable cross section
  - $\sigma(\pi^- p \to K^- \Theta^+) \sim 1\mu b$
- strongly related two results

- no significant structure has been observed.
- upper limit is 0.26μb/sr (90%C.L.) cf. 2.9μb/sr (E522)

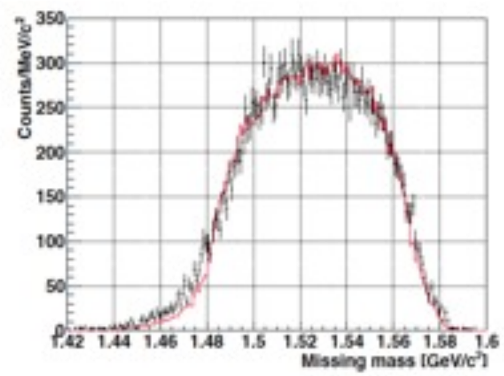


FIG. 2. The missing mass spectrum and the background shape for the $\pi^- p \to K^- X$ reaction at the beam momentum of 1.92 GeV/c. The black points with error bars are the experimental data. The contribution of the simulated background is indicated by red histogram.

Naruki @ 15th J-PARC PAC

Winter 2003

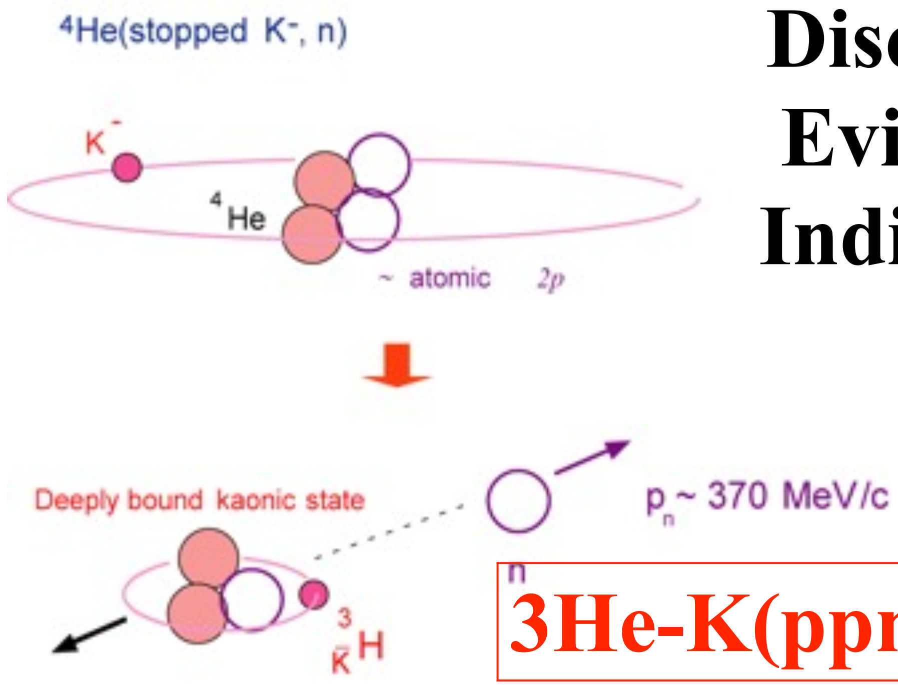
(discussion among collaboration)

(publication in 2004)

Kaonic Nuclei

Experimental Search

E471@KEK
Jun-July 2002



Discovery?
Evidence?
Indication?

3He-K(ppnK) system

	B_K	Γ_K
Observed	~173 MeV	~25 MeV
Predicted	~127 MeV	~30 MeV

M. Iwasaki, T. Suzuki et al.
Submitted to PLB

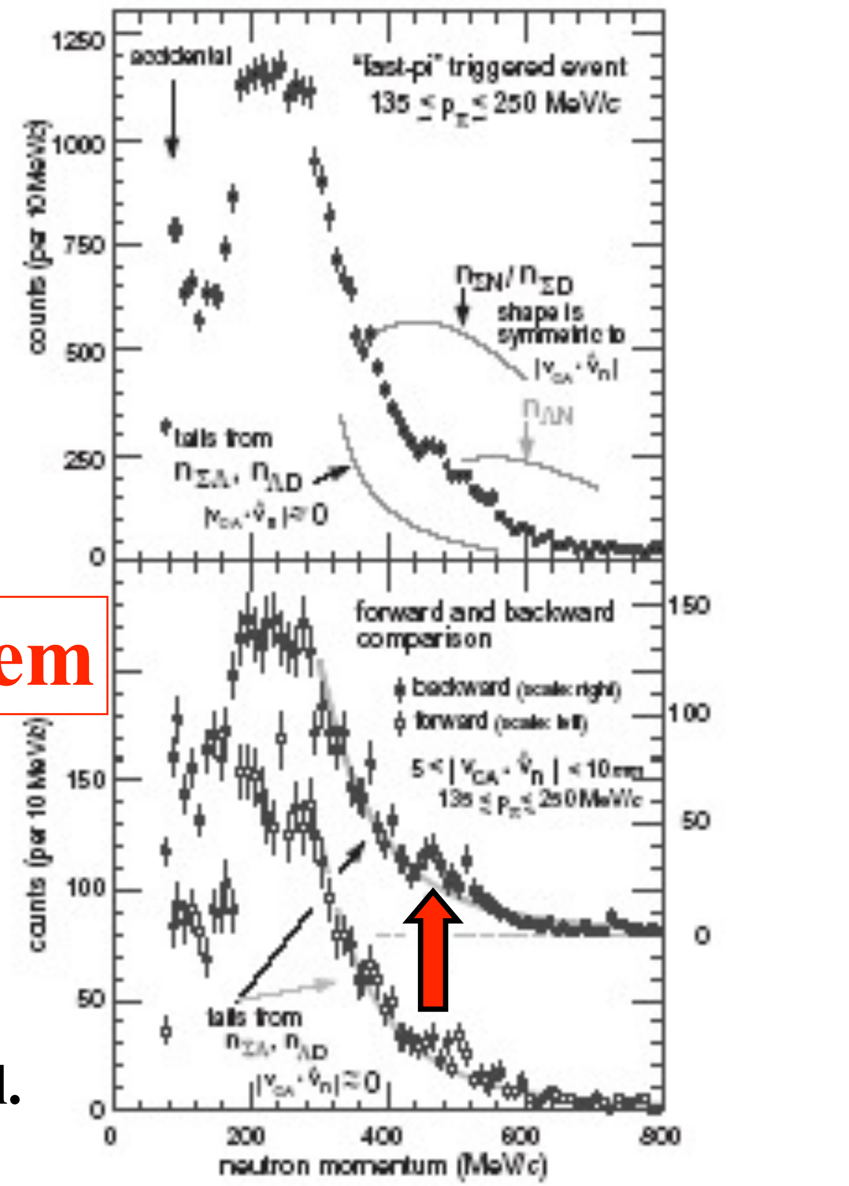
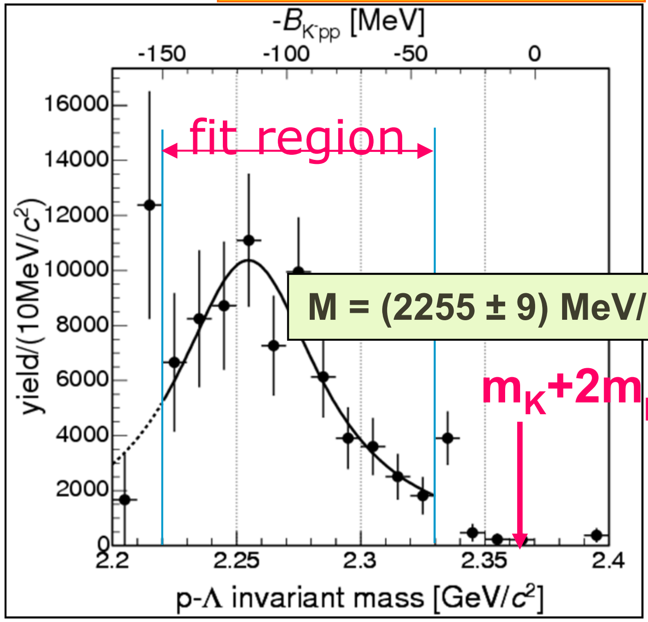


Fig. 4. Top: The neutron momentum spectrum measured in coincidence with a higher-momentum pion ($135 \le p_\pi \le 250$ MeV/c). Bottom: "backward" events (filled circles) (-10mm $< v_{CA} \cdot \hat{v}_n < -5$mm) and "forward" events (open circles) (5mm $< v_{CA} \cdot \hat{v}_n <$ 10mm) are selected and compared.

DEEPLY BOUND KAON STATES

FINUDA @DAΦNE
first observation
of the lightest DBKS in pΛ spectrum

PRL 94(2005)212303



K^-pp

K^- stopped in
Light targets ^{6}Li, ^{7}Li, ^{12}C

M = (2255 ± 9) MeV/c²

B = 115$^{+6}_{-5}$ (stat)$^{+3}_{-4}$ (sys) MeV

Γ= 67$^{+14}_{-11}$(stat)$^{+2}_{-3}$ (sys) MeV

Yield ≈ 0.1%/stopped K^-

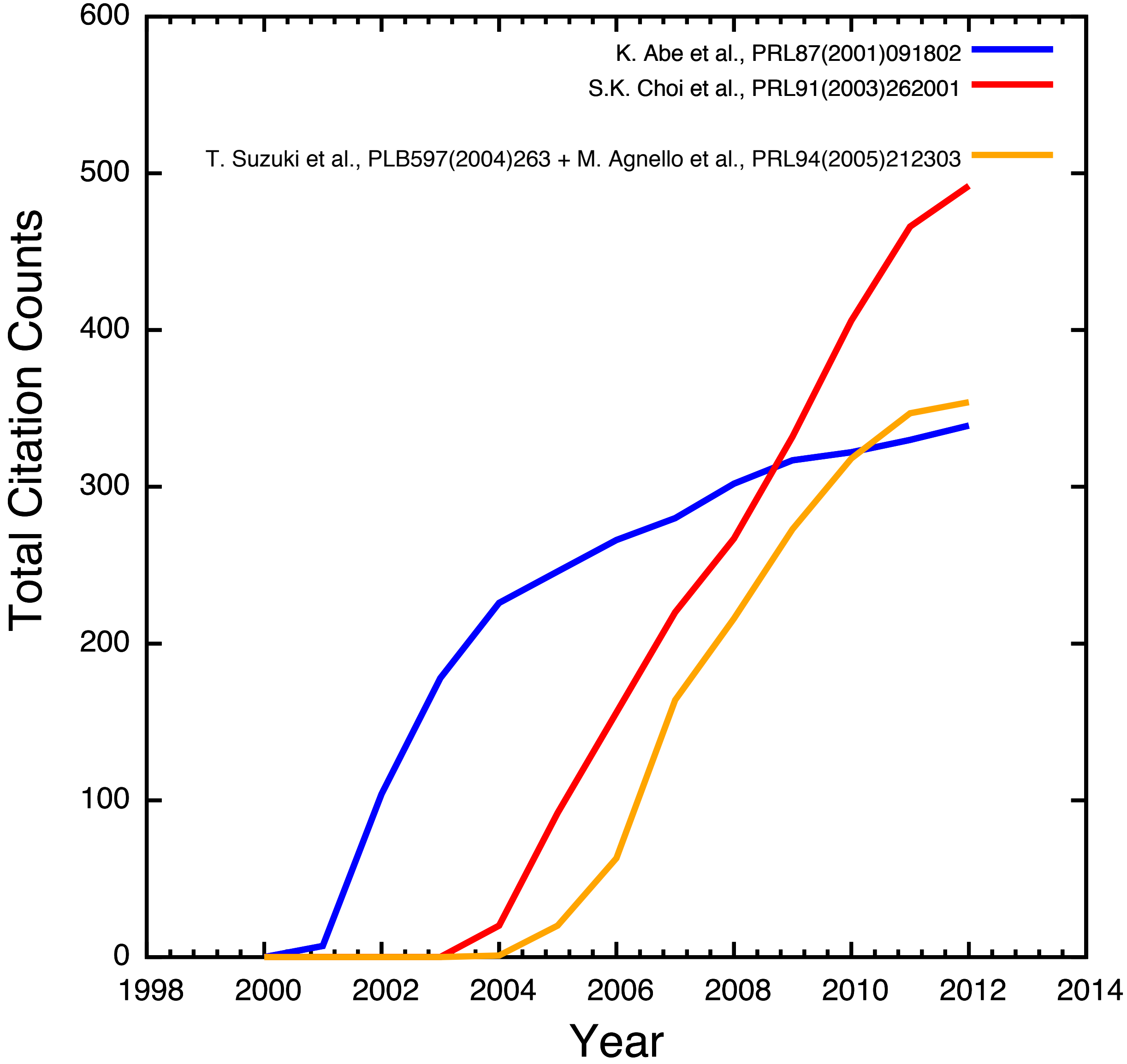
Akaishi-Yamazaki, PLB535(2002)
B=48MeV, Γ=61MeV

Shevchenko, PRL98(2007)
B=50-70MeV, Γ~100MeV

Ivanov, nucl-th/0512037
B=118 MeV, Γ~58MeV

K^-(pp) → X → Λp
→ Σ^0p → Λγ p

p Λ events strongly
back-to-back correlated

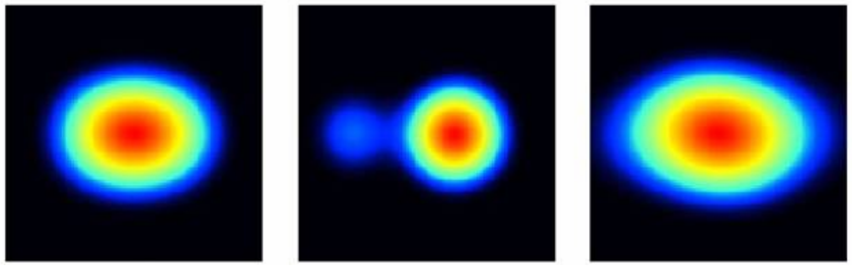


Data from Web of Knowledge

Mini – Workshop

on

Kaonic Nuclear Clusters



Institute for Medium Energy Physics

1090 Wien, Boltzmanngasse 3
Hörsaal – Room 38

Monday, Feb. 09, 2004, 14:00 – 17:00

Tuesday, Feb. 10, 2004, 10:00 – 17:00

Topics:
Kaonic atoms
Deeply bound kaonic systems:
- Experiments at KEK and GSI
- Theoretical predictions

MINI-WORKSHOP
KAONIC NUCLEAR CLUSTERS

Tentative Program

Monday, February 9th, 2004

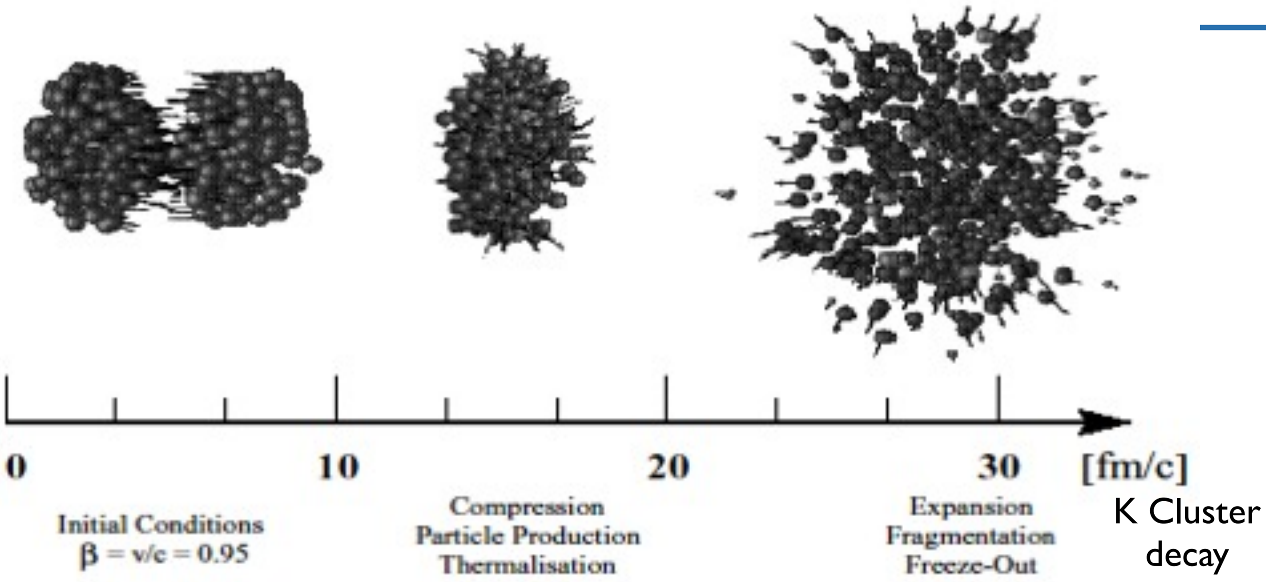
14.:00	P. Kienle Welcome and introduction of the goal of the workshop
14.20	T. Yamazaki, Tokyo Kaonic nuclear clusters, theoretical predictions and first experimental searches
15.:20	K. Suzuki, Munich Invariant mass spectroscopy of the decay of kaonic nuclear clusters
15:45	Ch. Fuchs, Tübingen Testing high density matter by kaon production in heavy iron reactions
16:45	Coffee Break
17:15	M. Cargnelli, Vienna Kaonic hydrogen X-ray spectra
17:45	Discussion on physics issues
18:30	Stadtheuriger im Esterhazykeller

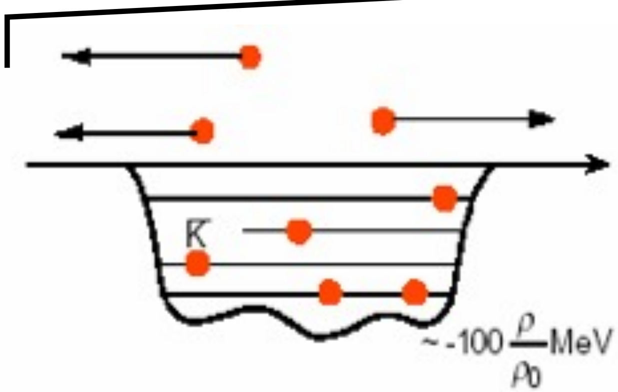
Tuesday, February 10th, 2004

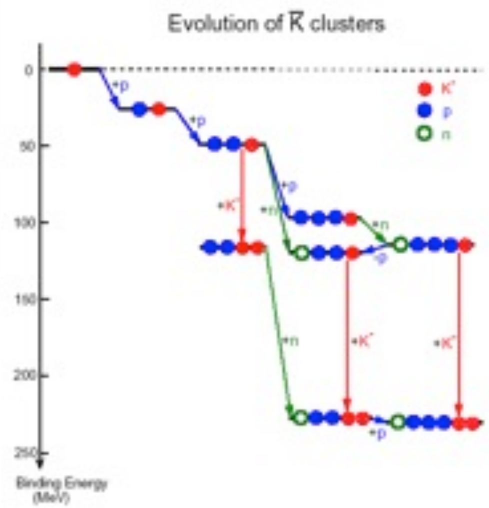
09:00	K. Suzuki, Munich and T. Yamazaki, Tokyo (pi,K)-reaction
09:30	R. Simon, Darmstadt Pion beams at GSI
10:15	Wisniewski, Darmstadt FOPI-Detector
10:45	P. Kienle KAOS as forward spectrometer
11:00	Coffee Break
11:30	Experimental procedures and problems (Kaon trigger missing mass, and invariant mass measurements)
12:30	Lunch
14:00	Continuation of discussion on experimental procedures and problems
17:00	Summary and end of the workshop

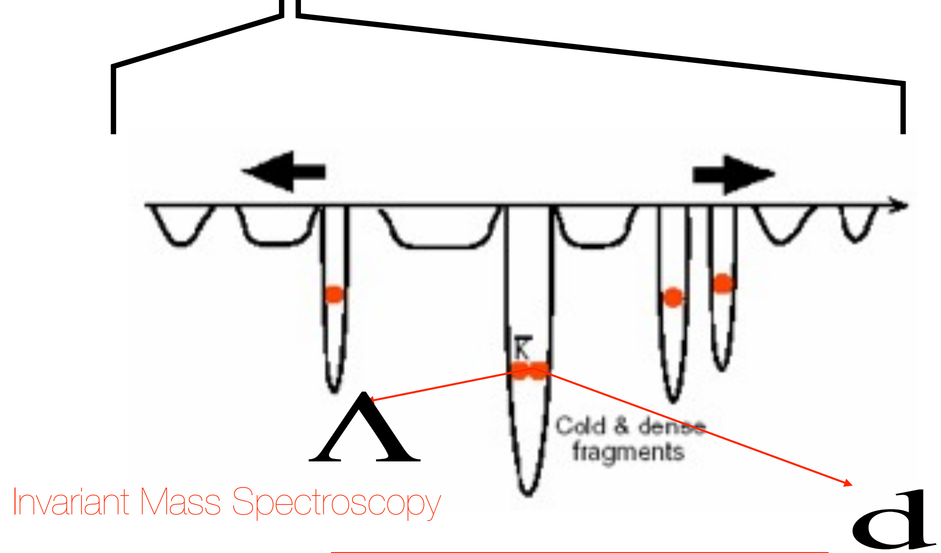
with Heavy-Ion-Collision

K^- cluster fragments in HI reactions









Density: $3\rho_0$

Temperature: ~100MeV

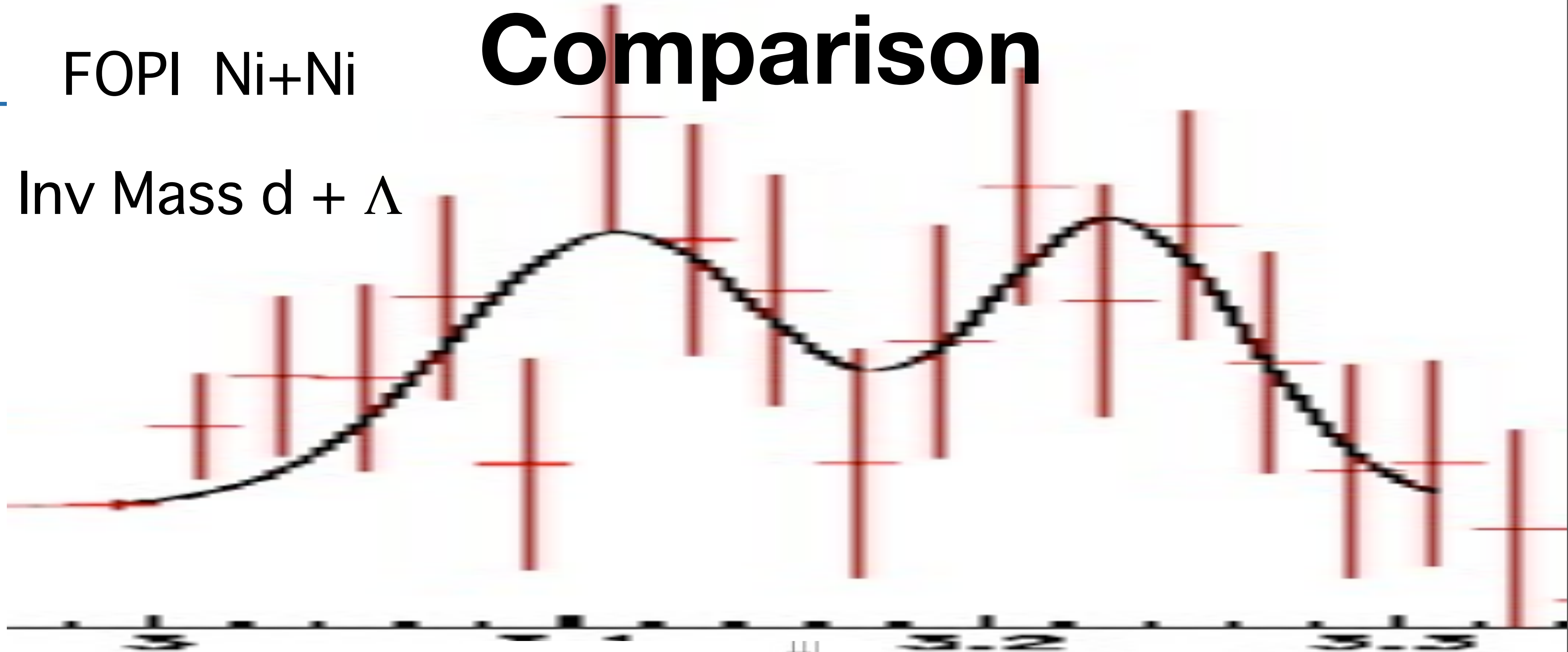
Kpp ® Λ + p

Kppn ® Λ + d

Comparison

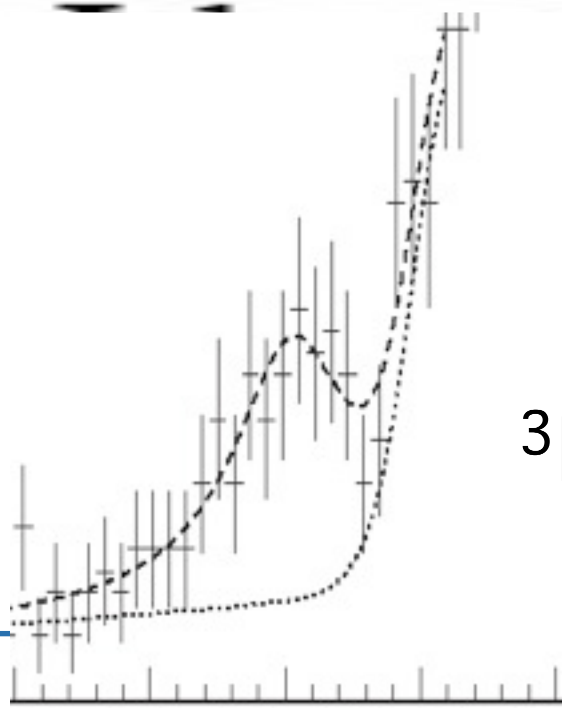
FOPI Ni+Ni

Inv Mass d + Λ



KEK-KNUCL

$^{3}He(K^{-},n)ppnK^{-}$



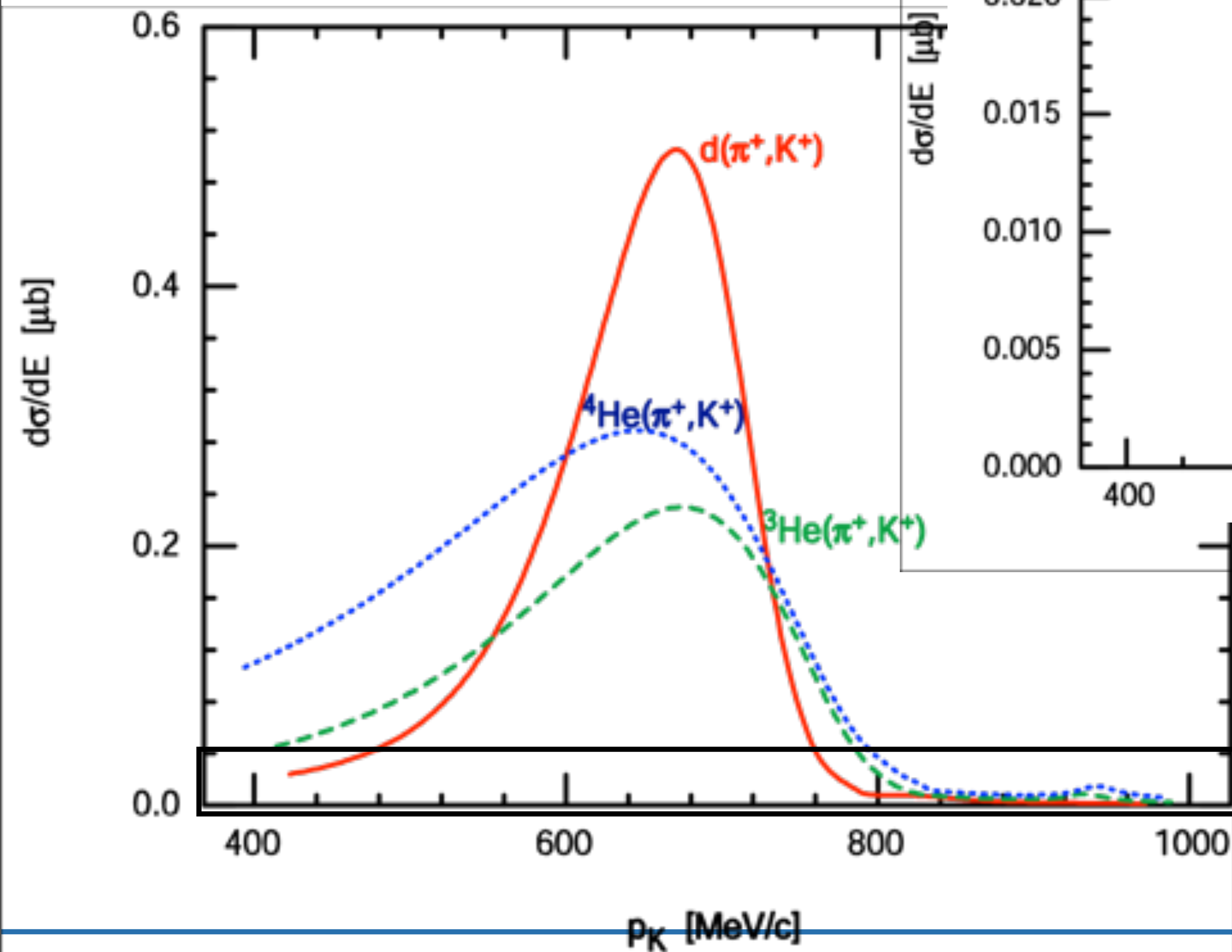
Dedicated Experiment

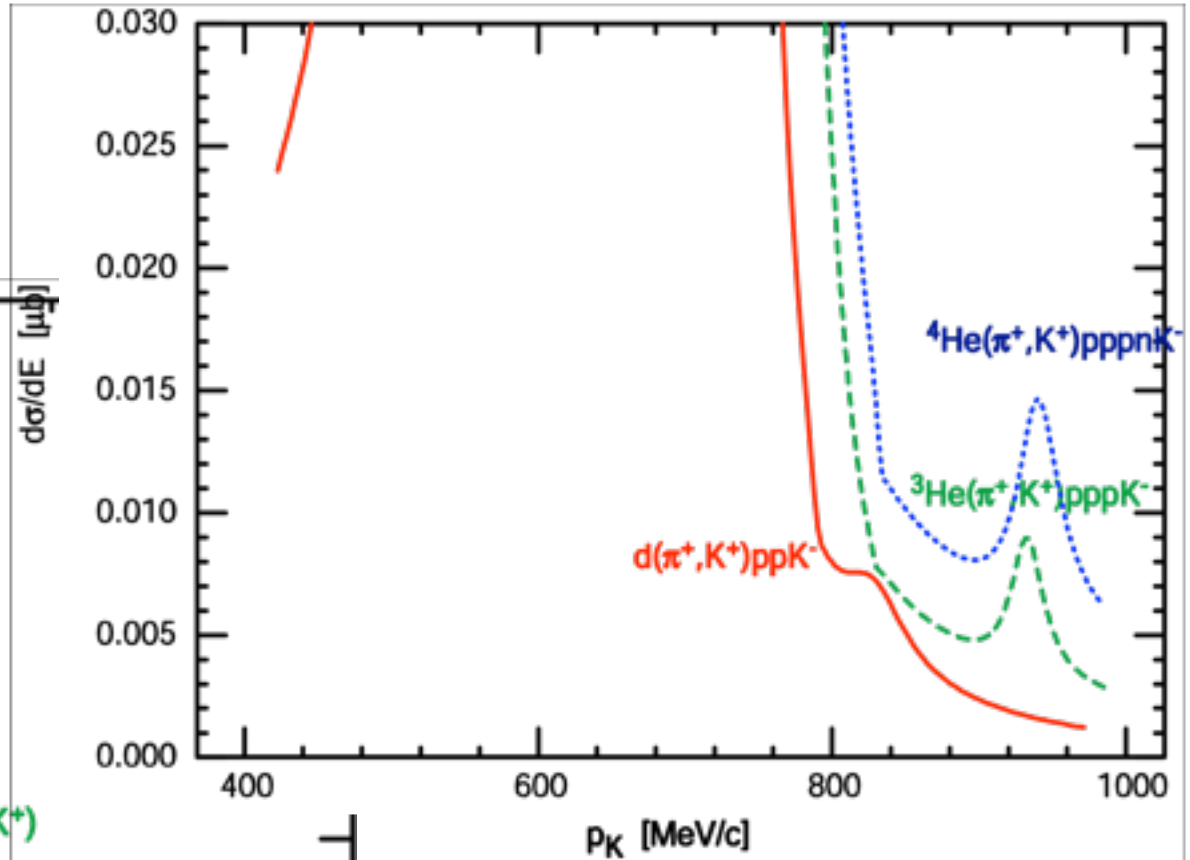
(π,K) reactions

BE: 48MeV
Γ: 61MeV

	(π^-,K^0)	(π^+,K^+)	(π^+,K^0)
ΔQ	-1	0	1
Target			
p	Λ, Λ^*	Σ^+, Σ^{++}	
[n]		Λ, Λ^*	Σ^+, Σ^{++}
d	pnK^-	ppK^-	
^3He	$ppnK^-$	$pppK^-$	
^4He	$ppnnK^-$	$pppnK^-$	$ppppK^-$

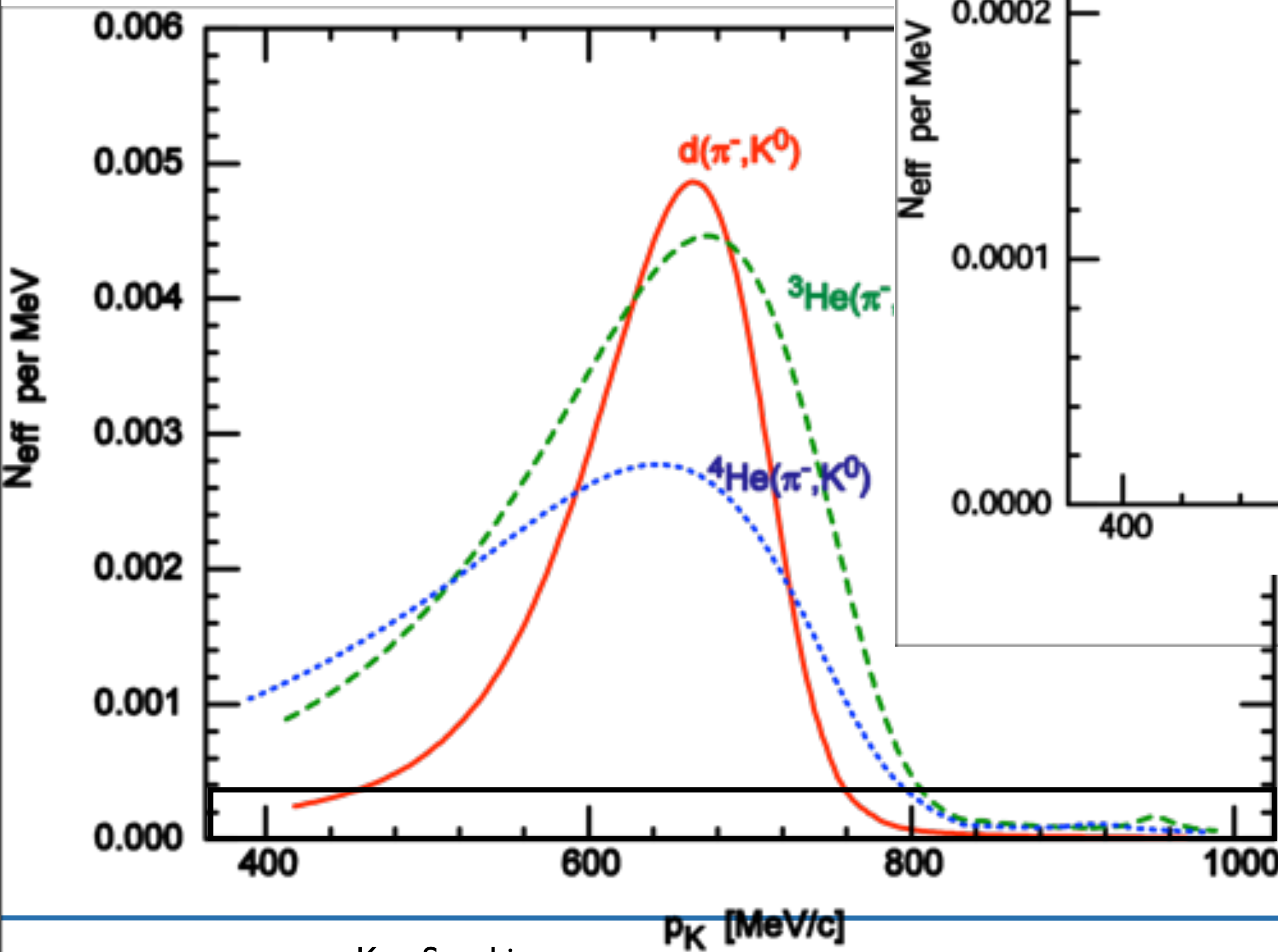
(π^+,K^+) Spectra

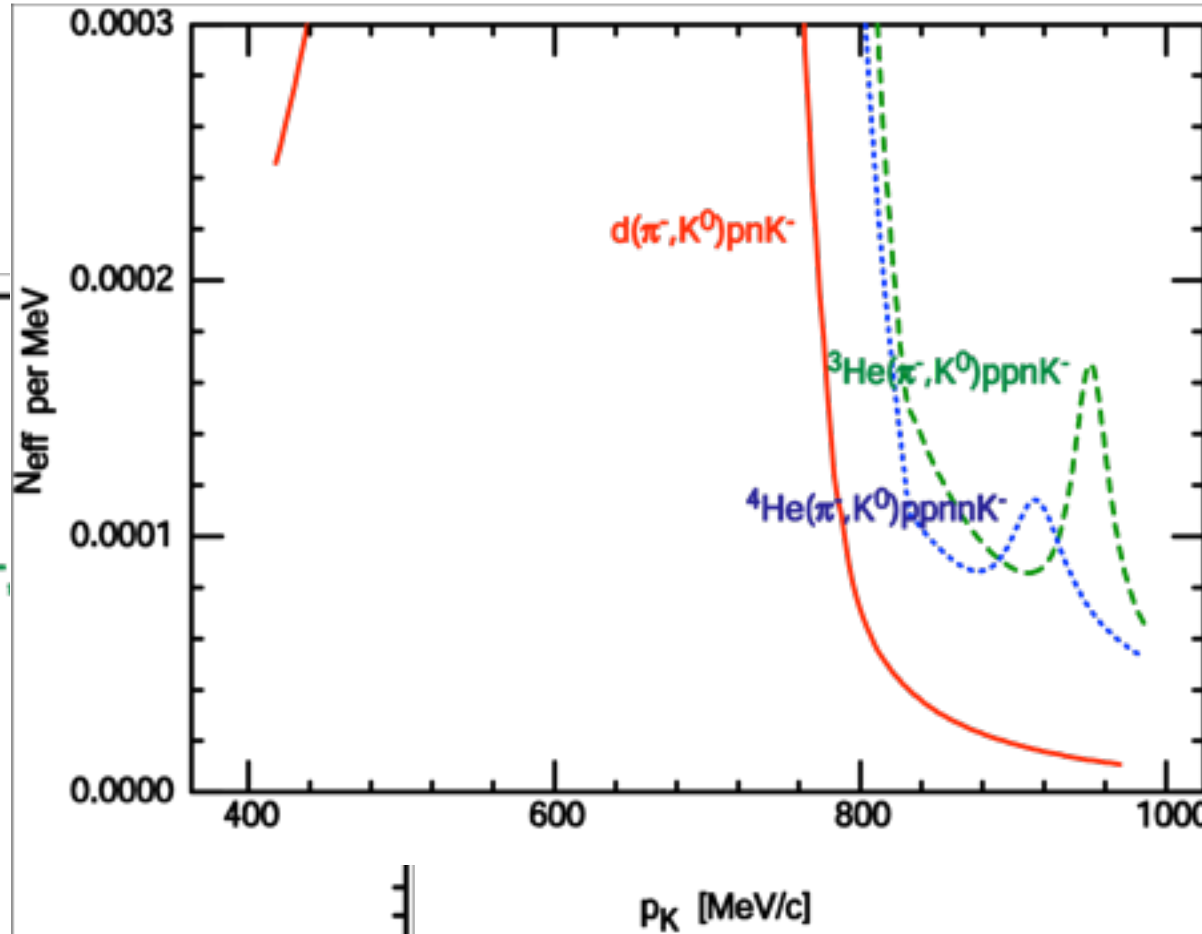




Akaishi 2004

(π^-,K^0) Spectra



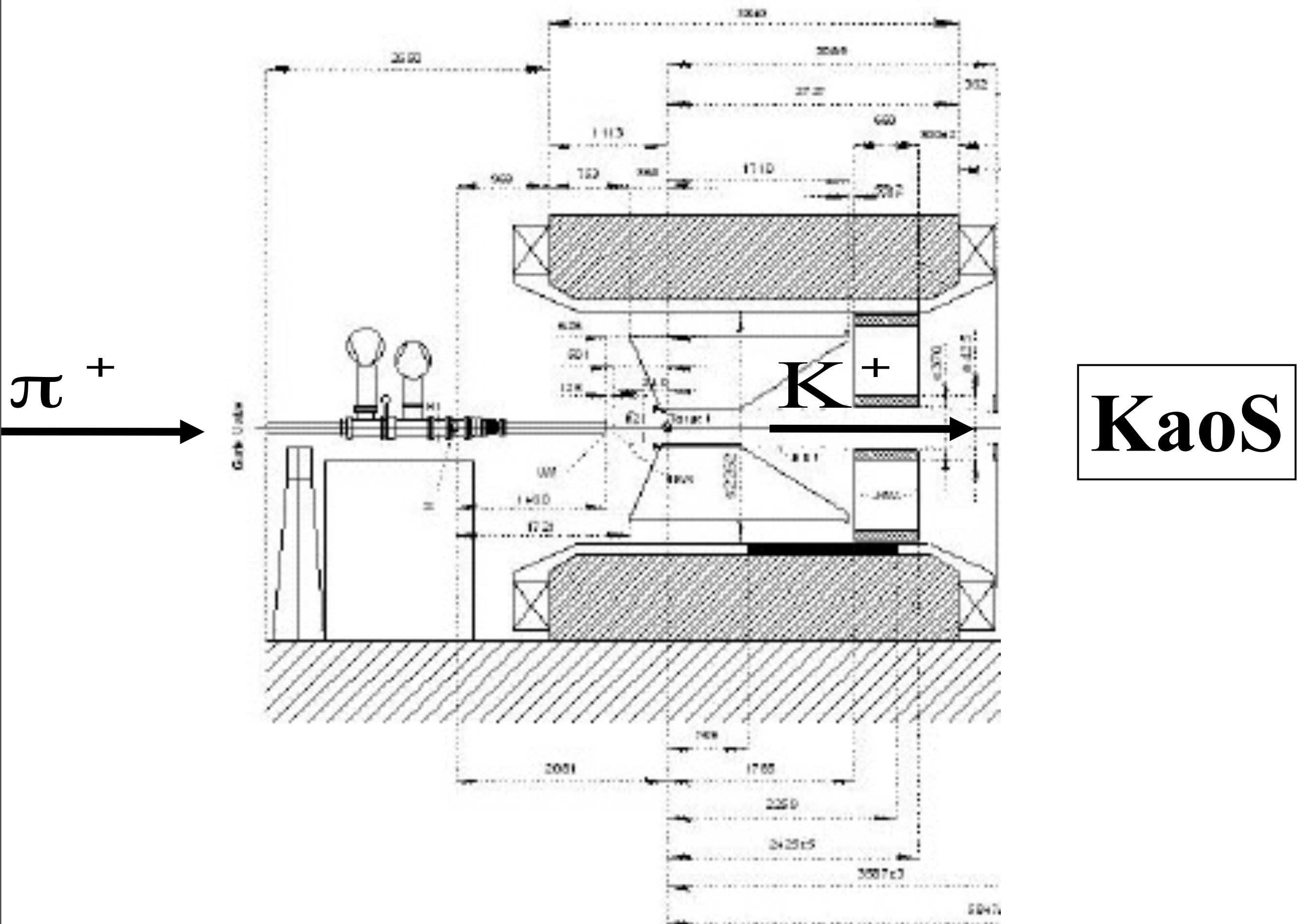


Akaishi 2004

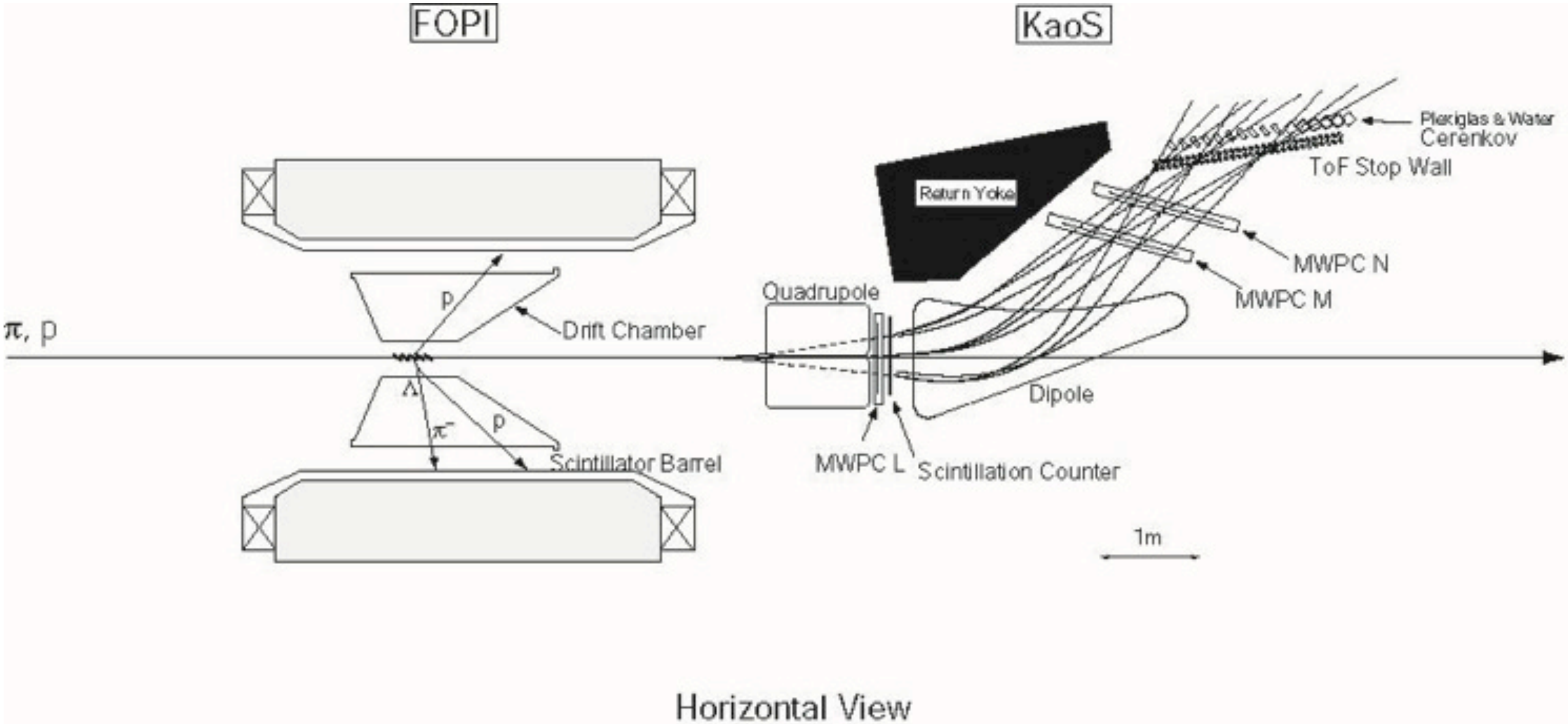
Setup

h 2.6m x l 6m

Q aperture: 30cm

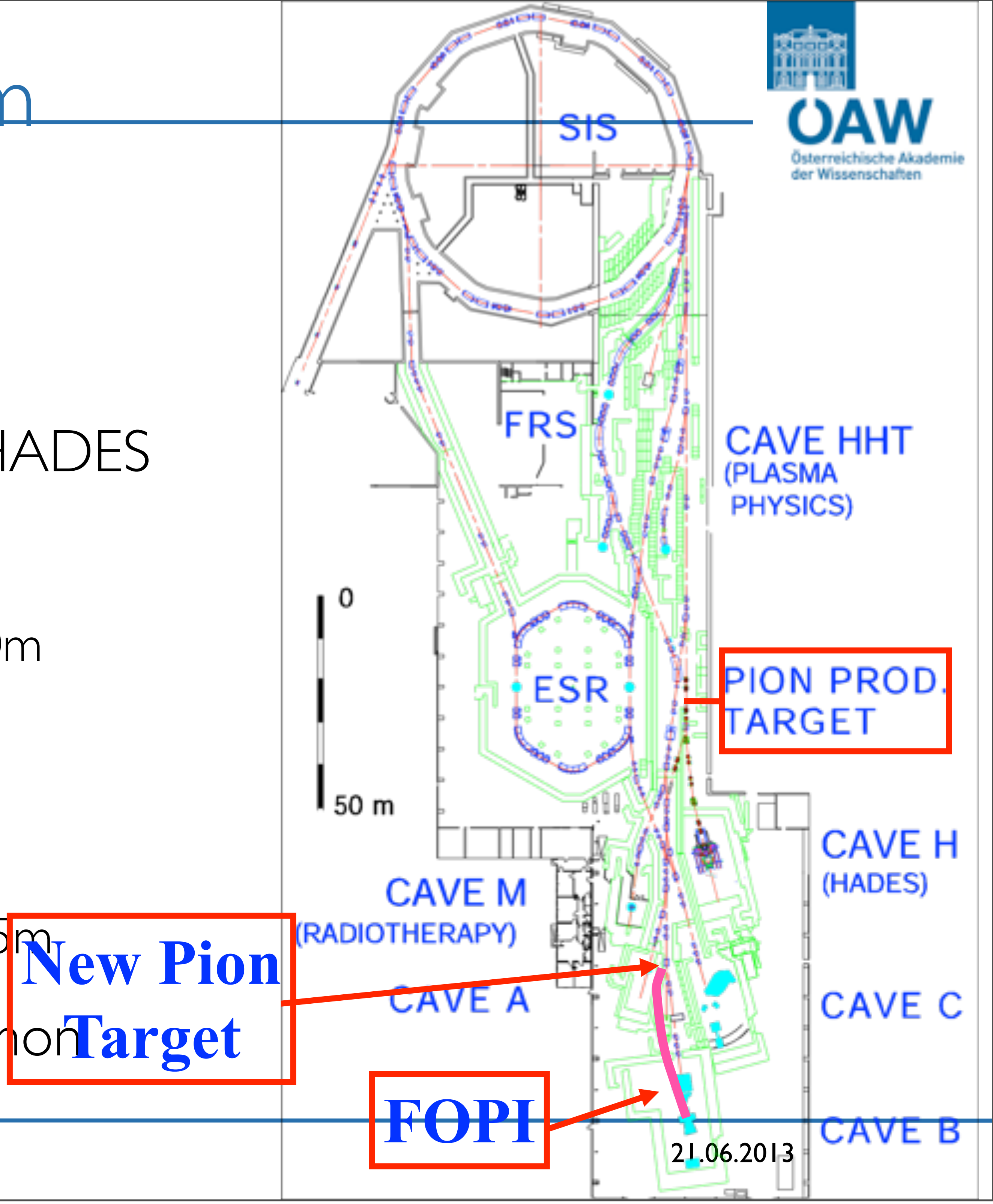


FOPI+KaoS Spectrometer?


FOPI
KaoS
Plexiglas & Water
Cerenkov
ToF Stop Wall
Return Yoke
MWPC N
MWPC M
Quadrupole
p
Drift Chamber
π, p
Λ
π⁻
p
Dipole
Scintillator Barrel
MWPC L
Scintillation Counter
1m
Horizontal View

Pion Beam

- Pion target before HADES
  - 10^5/spill
  - Long flight path - 80m
- New Pion Target
  - 10^6/spill
  - Short flight path – 25m
- More detail by R. Simon

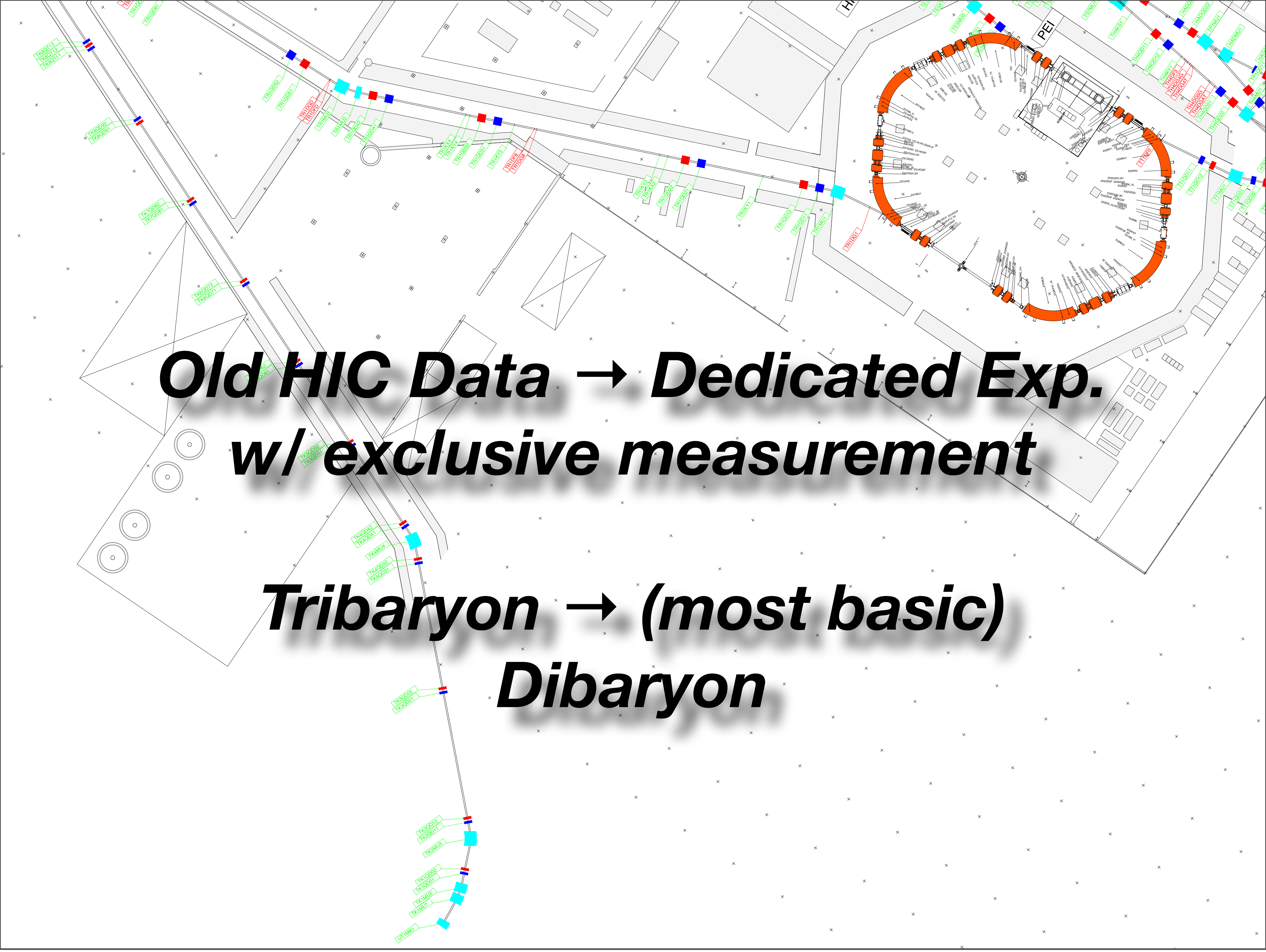


Summary

Missing mass spectroscopy + Invariant mass spectroscopy

KaoS Spectrometer + FOPI

- The most fundamental d(π+,K+)ppK system as a first step
  - Important both experimental and theoretical point of view
- Byproduct $^{12}C(\pi,K)$ reaction in CD_2



Old HIC Data → Dedicated Exp. w/ exclusive measurement

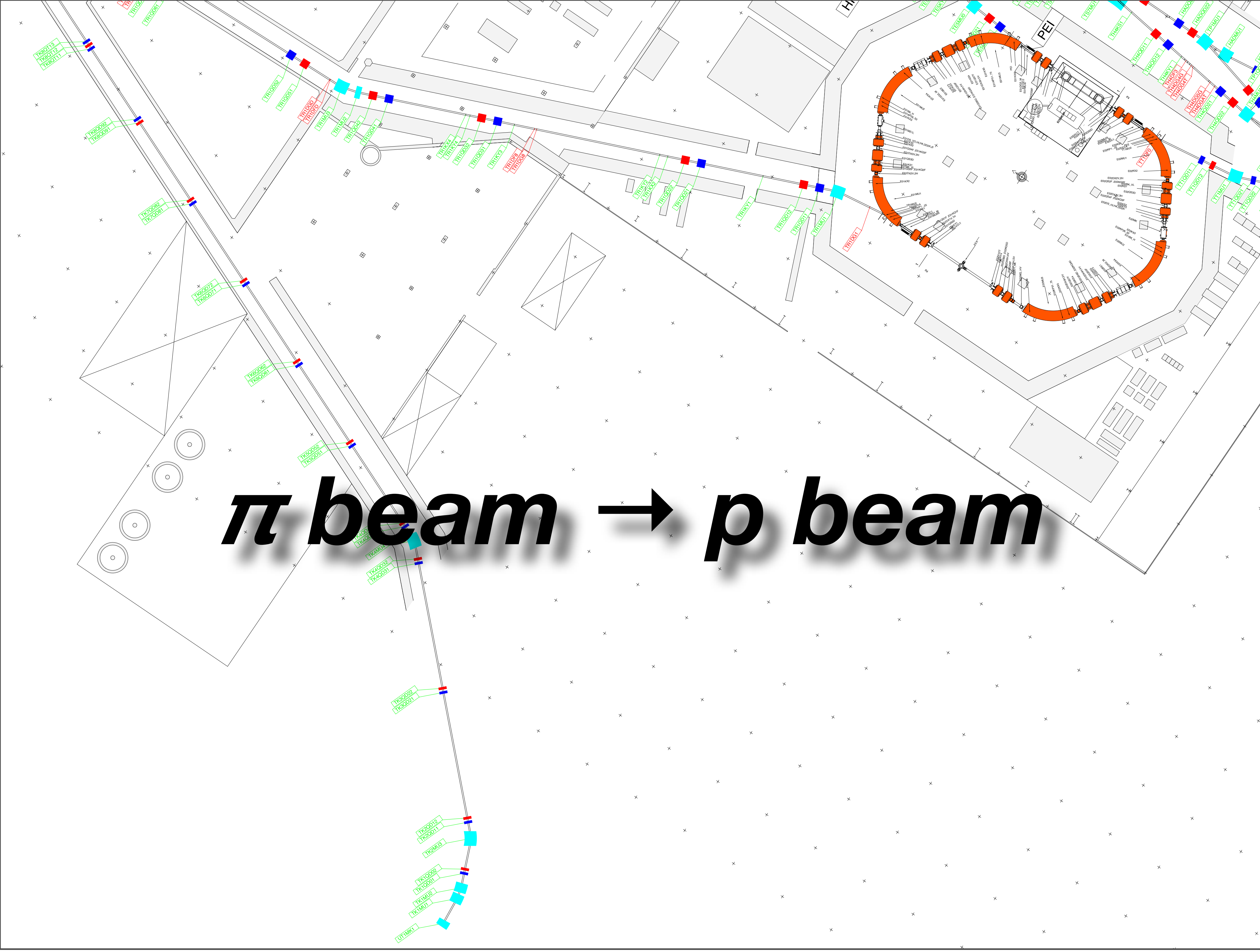
Tribaryon → (most basic) Dibaryon

2004 Faschingsfeier at IMEP

2004 Faschingsfeier at IMEP


VERHALTEN IM BRANDFALLE

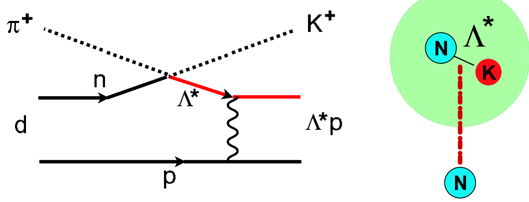
π beam → p beam

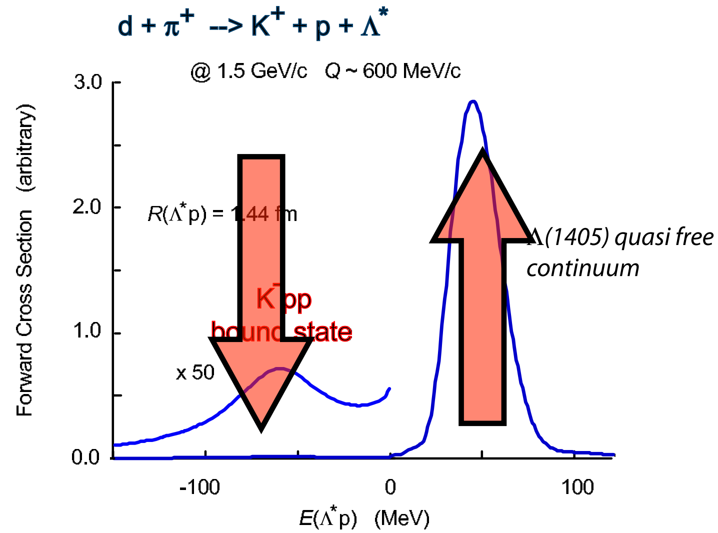


NN reaction vs. πK reaction

weakly coupled Λ^* doorway

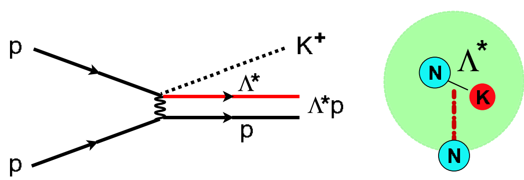
π^+ + "n" --> "Λ^*" + K^+
"Λ^*" + "p" --> bound K^-pp minor
--> quasi-free Λ^* dominant

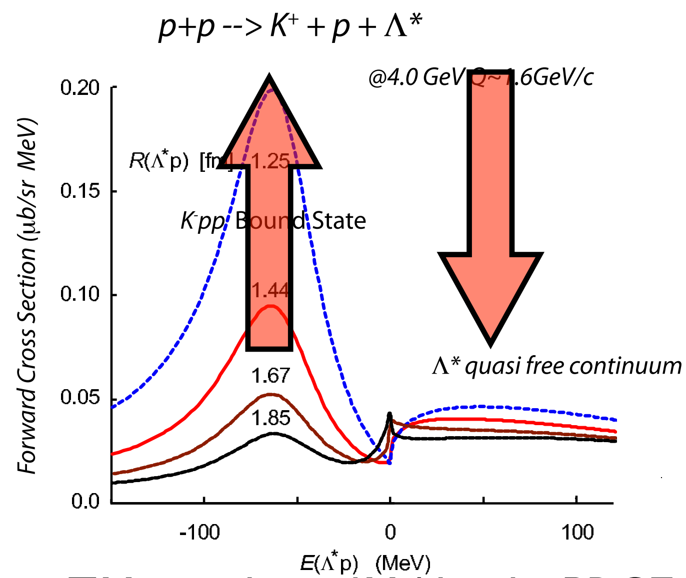




strongly coupled Λ^*p doorway

pp --> K^+ + Λ^*p
bare Λ^*p --> bound K^-pp dominant
--> quasi-free Λ^*





T. Yamazaki and Y. Akaishi, PRC76 (2007) 045201

$$p + d \rightarrow \underline{\Lambda^* + p} + K^0 + p$$

$$\Lambda^* + p \rightarrow K^- pp$$

$$K^0 \rightarrow \pi^- \; \pi^+$$

$$K^- pp \rightarrow \Lambda \; p$$

$$\Lambda \rightarrow \pi^- \; p$$

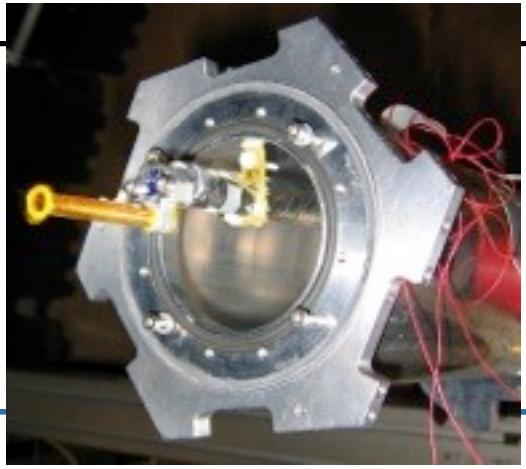
Missing Mass: K^0+p

Invariant Mass: $\Lambda(\pi^-+p)$+p

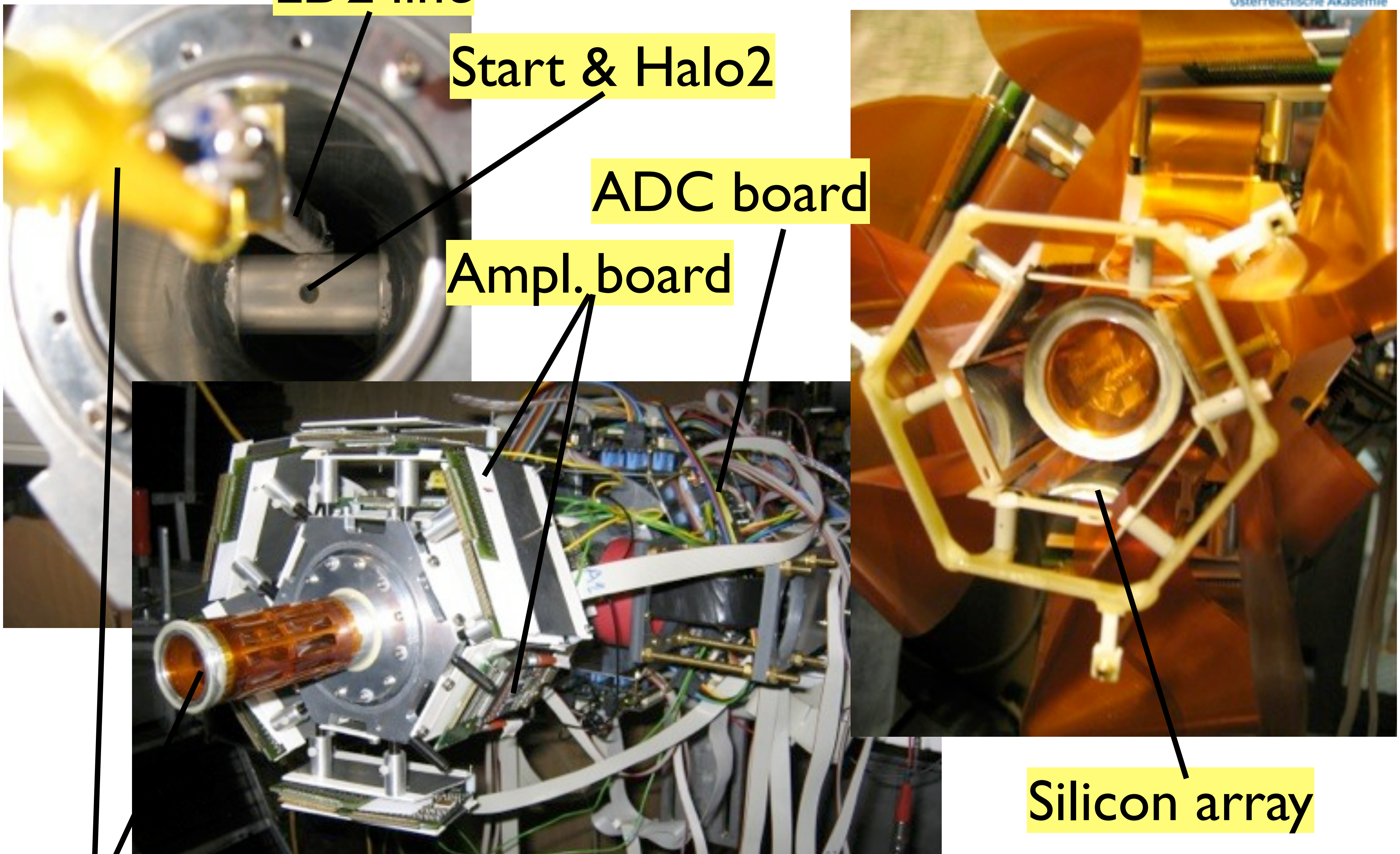
6 Charged Particles

Experimental Conditions

	Previous	Present
Target	ø=5mm, L=4cm	



Target Region Setup (previous: p+d)



Experimental Conditions

	Previous →	Present
Target	ø=5mm, L=4cm	ø=35mm, L=1cm

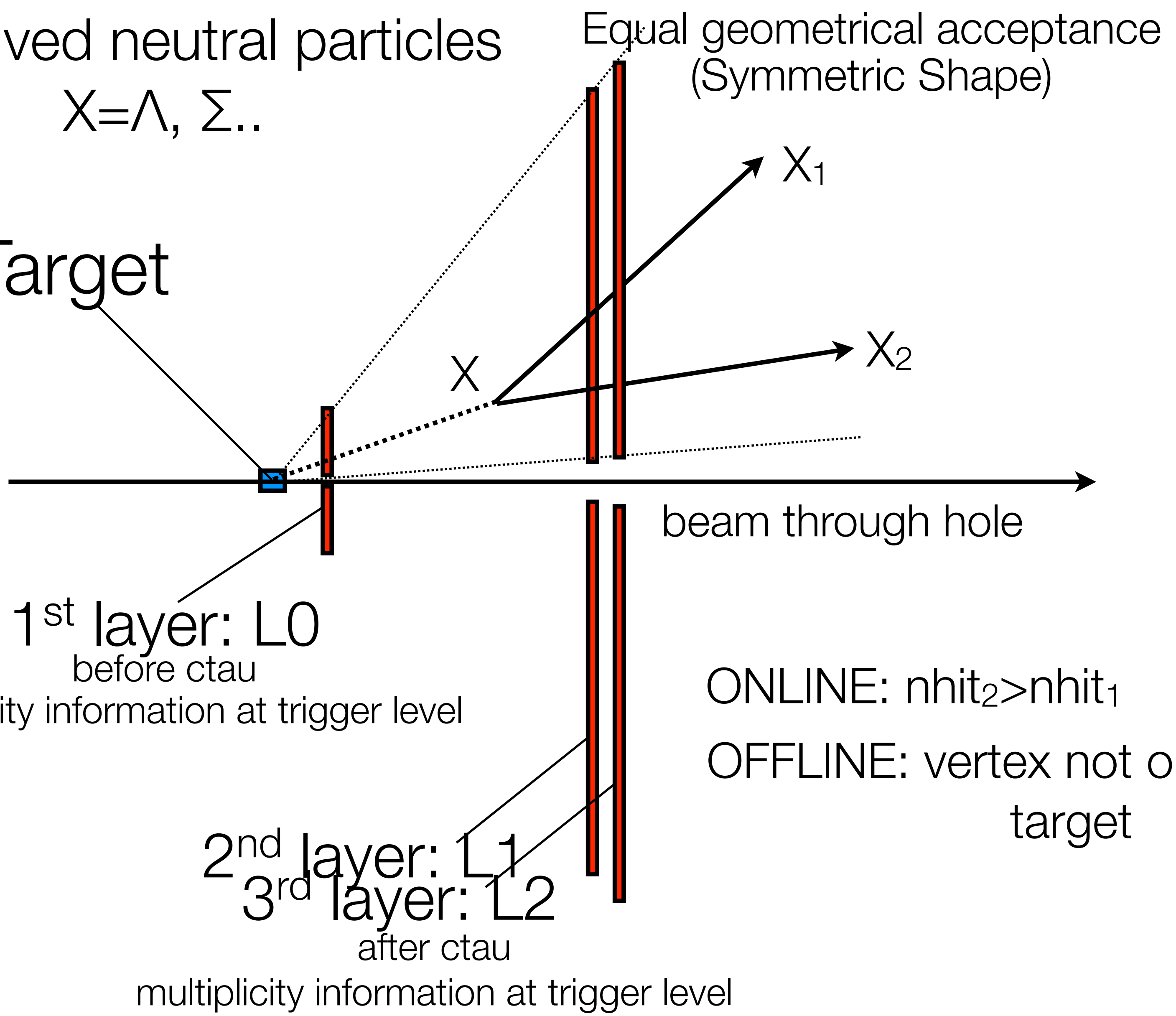
Experimental Conditions (+)

	Previous	Present
Target	ø=5mm, L=4cm	ø=10mm, L=1cm
Kaon Identification	$K^0 \rightarrow \pi^+ + \pi^-$	K^+ (<1GeV/c with RPC)
Trigger	CMUL=6 ~1/100	CMUL=4 ~1/10

Strangeness Production ⇒ Lambda Trigger

Lambda Trig: Basic Concept

Short-lived neutral particles
X=Λ, Σ..

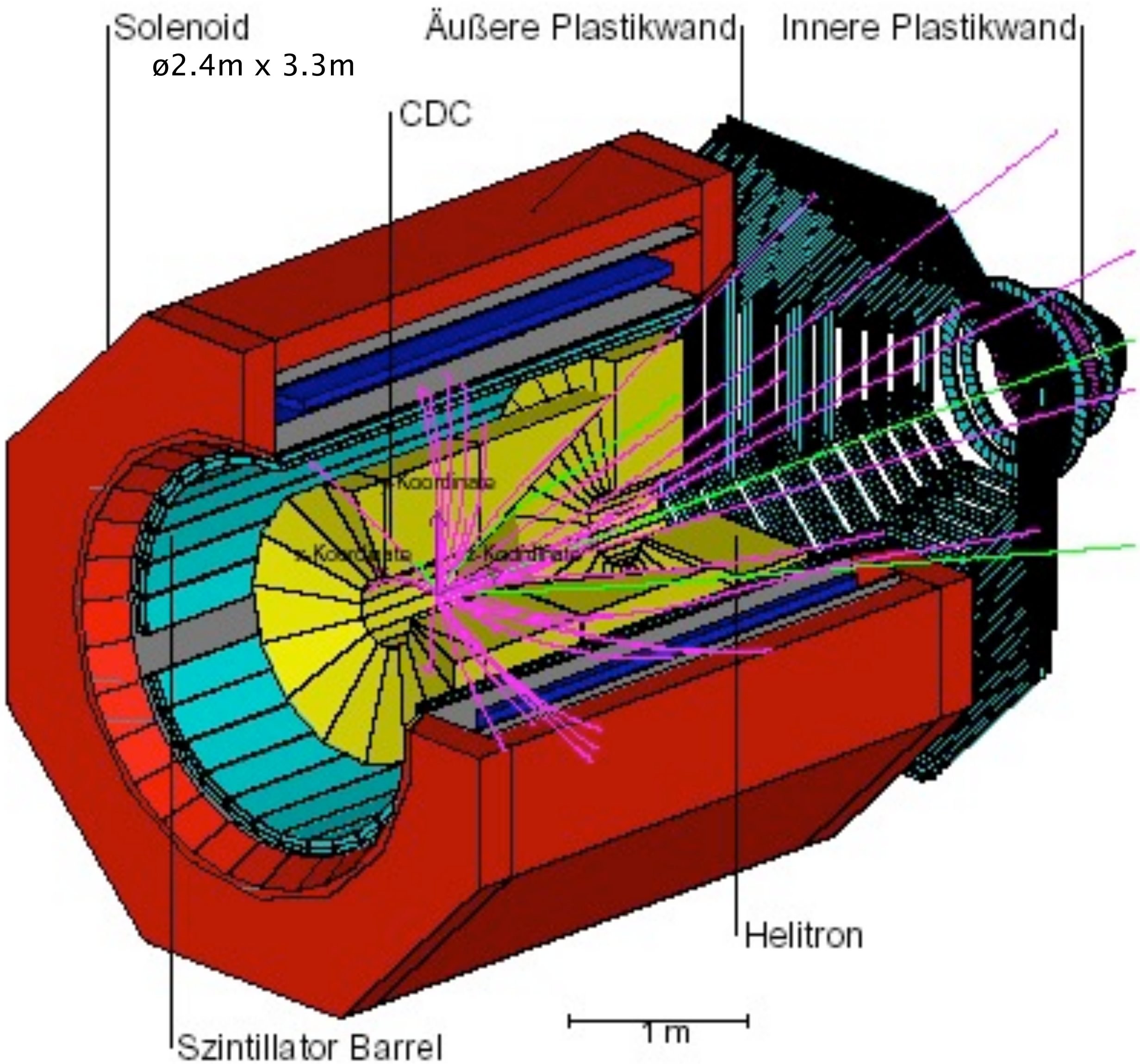


ONLINE: $nhit_2 > nhit_1$

OFFLINE: vertex not originate from target

FOPI Detector

Fixed target experiment designed for heavy-ion-collision study



Magnetic Field: 0.6T
Trigger Rate: 200~500Hz
Particle/event: ~100

θ_{lab}	Tracking	TOF
35-150	CDC	Sci. Barrel
7.5-35	Helitron	PLAWA
1.2-7.5		ZD

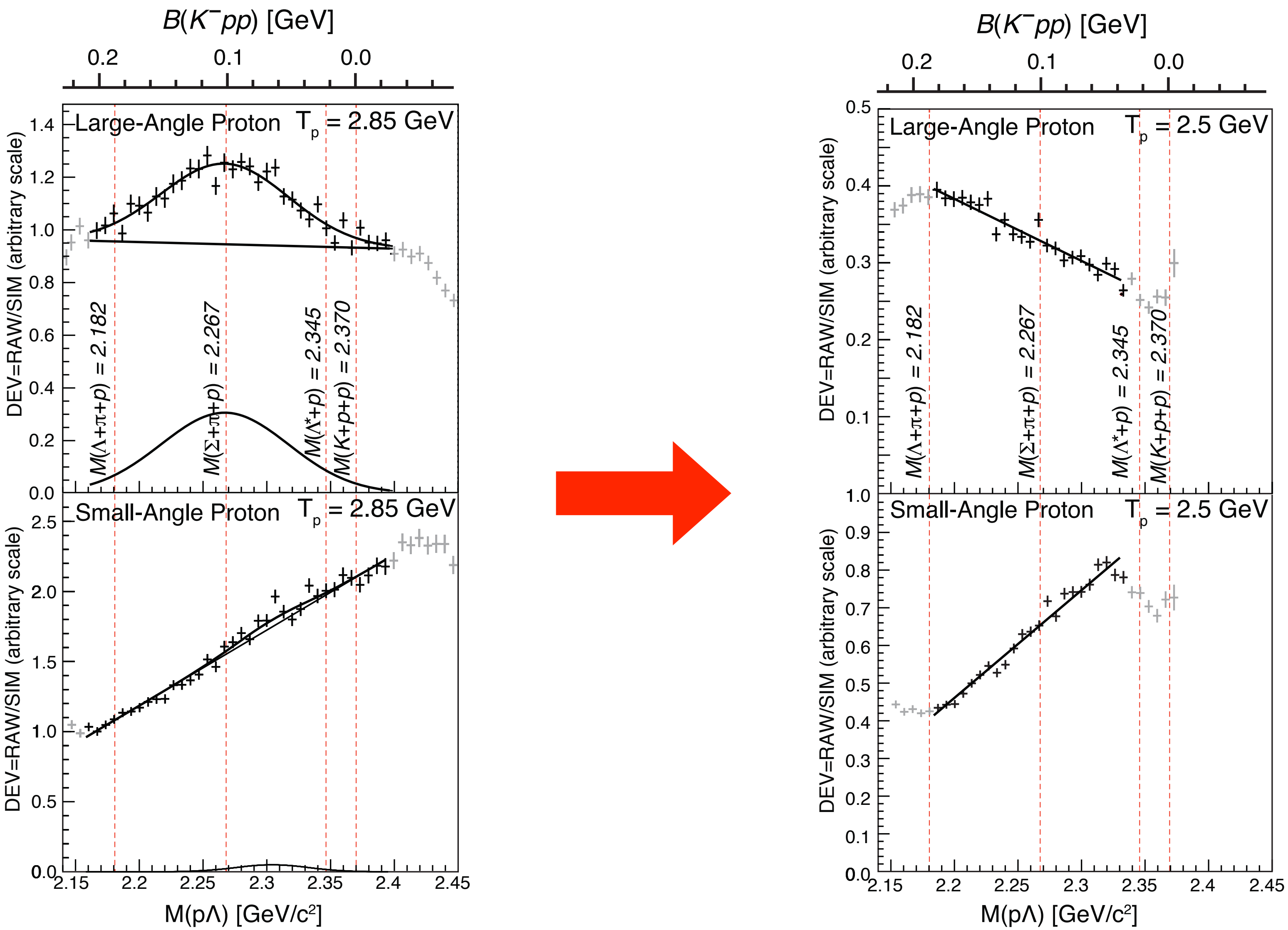
K. Wisniewski Ph.D.Thesis
R. Kutsche Ph.D.Thesis

DISTO

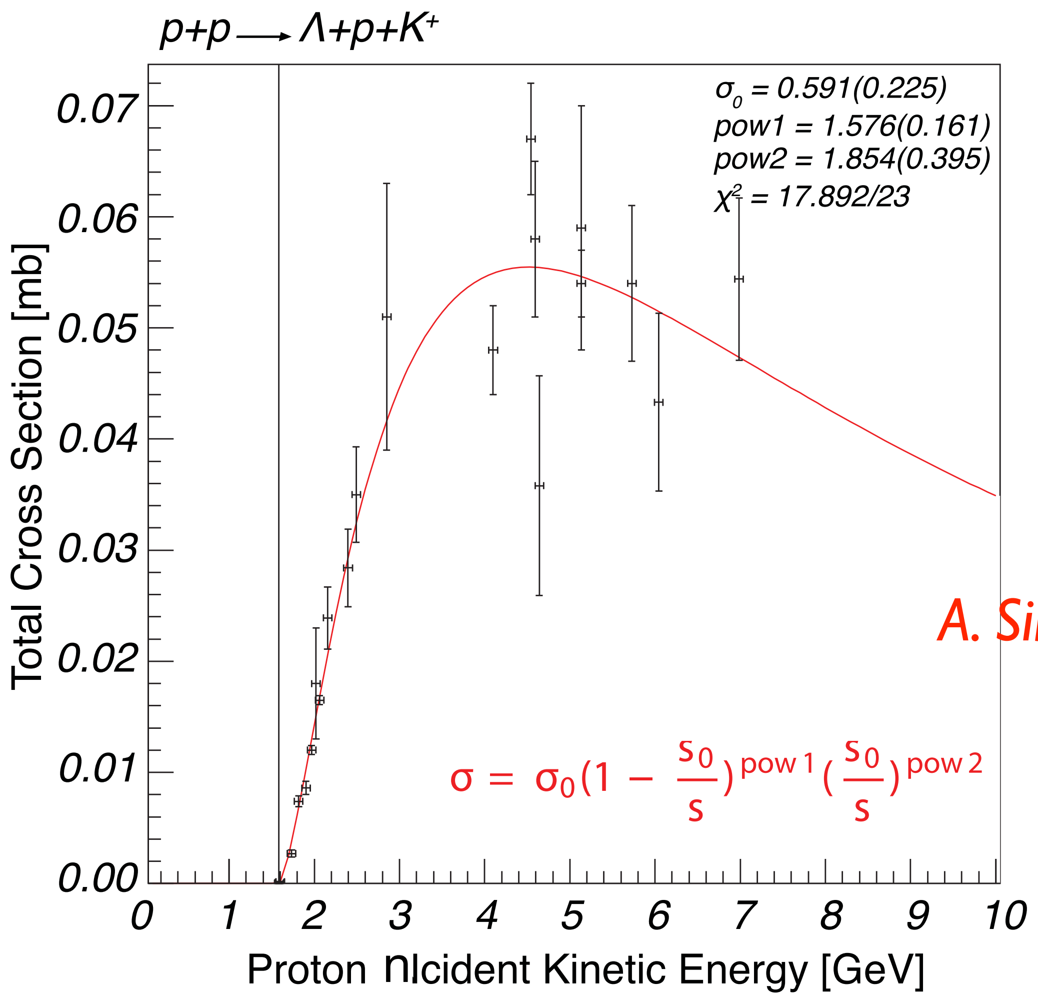
Paul, Marco, Toshi, Ken
2005 (EXA05) -

Energy Dependence of the Formation of X(2265)

DISTO $pp \rightarrow p\Lambda K^+$ data at 2.5 GeV



$pp \rightarrow pYK^+$ cross section energy dependence



$$\sigma = \sigma_0 (1 - \frac{s_0}{s})^{pow\,1} (\frac{s_0}{s})^{pow\,2}$$

A. Sibirtsev, PLB359(1995)29

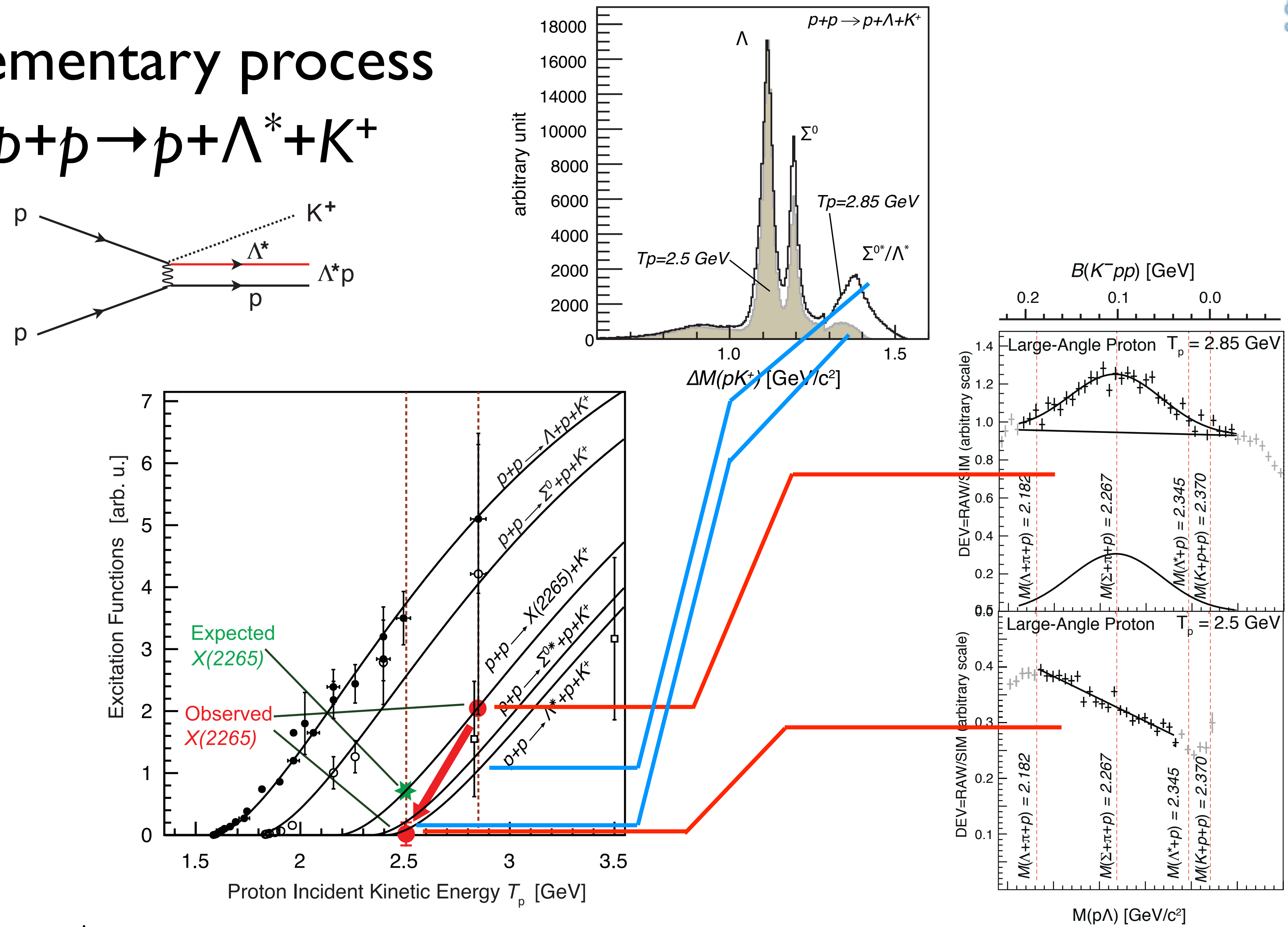
Landolt-Börnstein + COSY (COSY-11/COSY-TOF)

KS2010

Energy Dependence

elementary process

$p+p \rightarrow p+\Lambda^{*}+K^{+}$



Λ*(1405) involved in the X(2265) production mechanism?

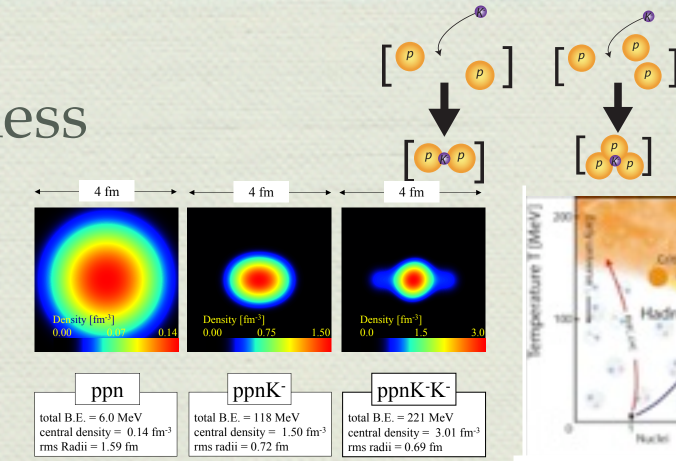
Summary

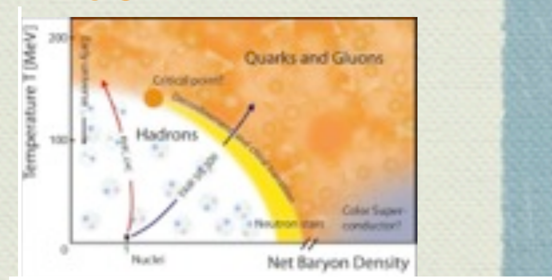
- Non-observation of X(2265) at 2.5 GeV is actually consistent with the picture that the X(2265) being a kaonic nuclei.
- This argument will be critically tested with FOPI data at 3.1 GeV.

KN(=Σπ) Int. from $\Lambda_c \rightarrow \pi\pi\Sigma$ decay

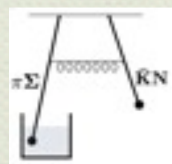
Ken Suzuki

- Hadron physics with strangeness
  - Deeply bound kaonic states

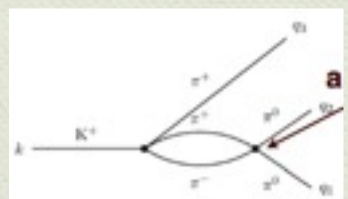


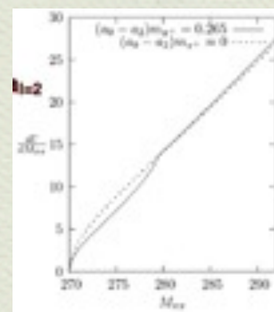


- $KN(=\pi\Sigma)$ interaction as a fundamental interaction / input
  - $\pi\Sigma$ scattering length: a missing piece



- $\pi\pi$ scatt. length from $K^+ \rightarrow \pi^+\pi^0\pi^0$ decay (Cabibbo)





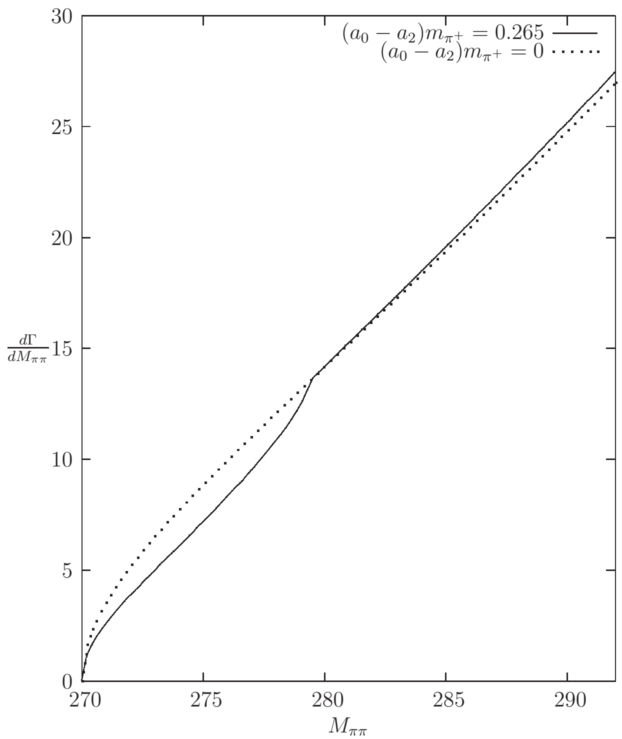
T. Hyodo and M. Oka, PRC84(2011)035201, N. Cabibbo, PRL93(2004)121801

$\pi\Sigma$ analogue to $\pi\pi$

$\pi\pi$ case

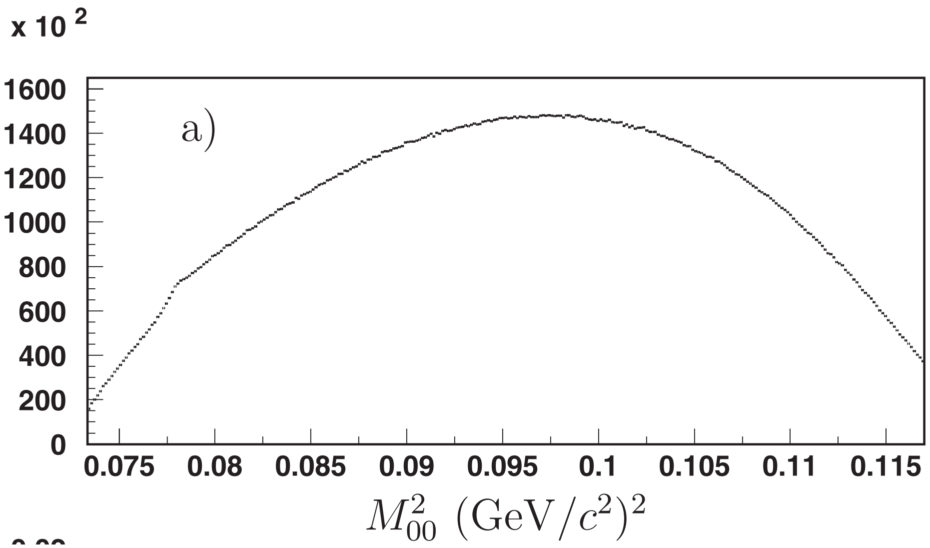
Theory

Cabibbo, PRL 93 (2004) 121801



Measured NA48/2 Collaboration

Batley et al., PLB 686 (2010) 101

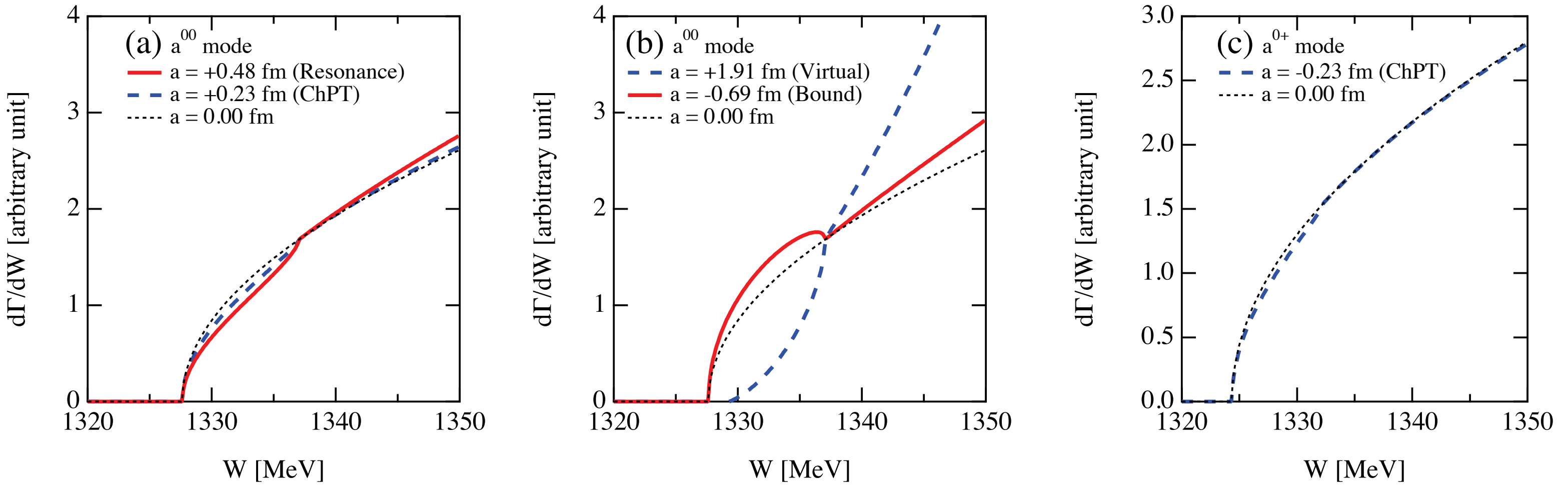


- from fit to IVM($\pi^0\pi^0$) the $\pi\pi$ scattering length is deduced

$\pi\Sigma$ analogue to $\pi\pi$

$\pi\Sigma$ case

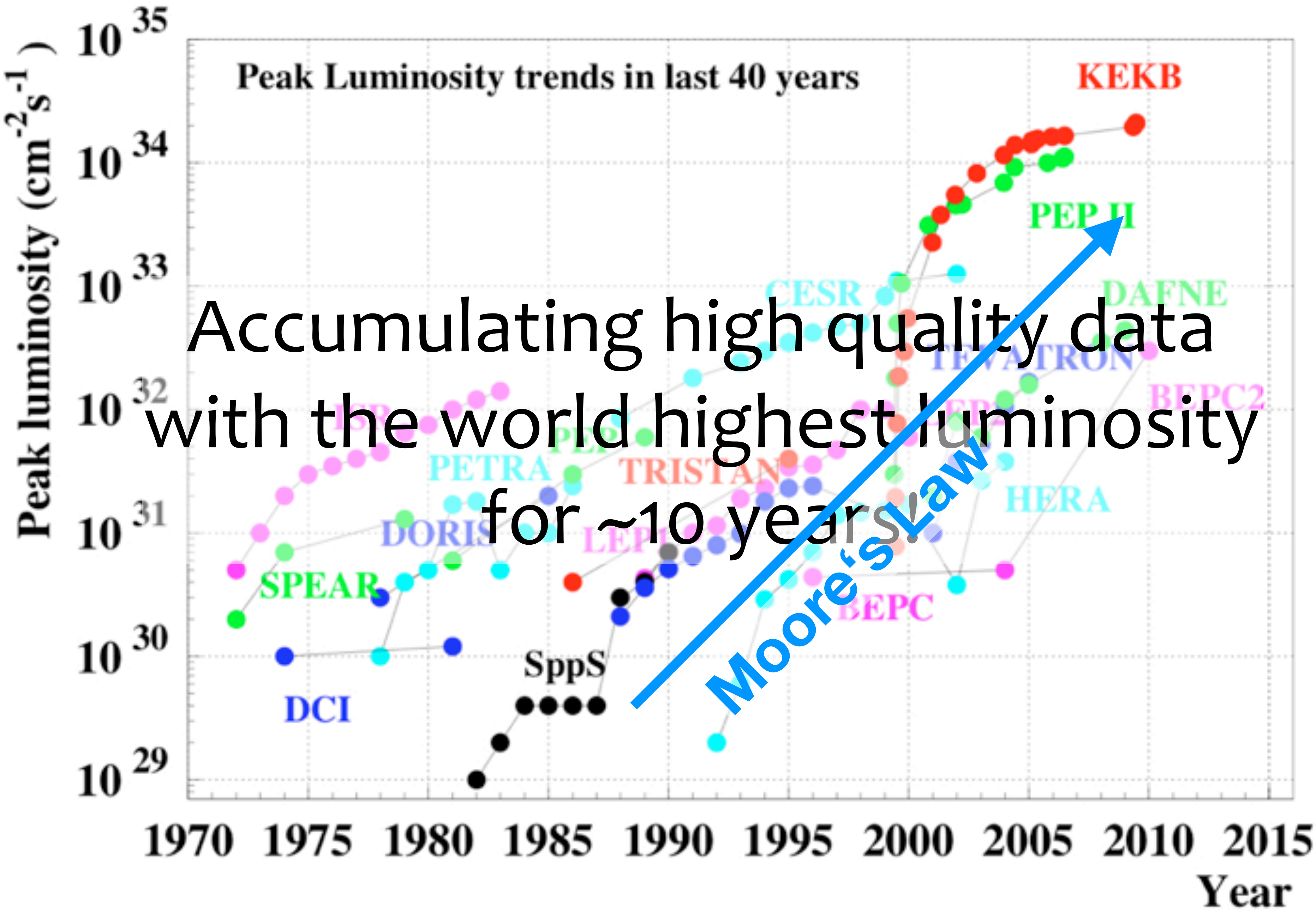
- decay $\Lambda_c \rightarrow \pi\pi\Sigma$ is investigated
- different charge states of $(\pi\Sigma)$ can be considered



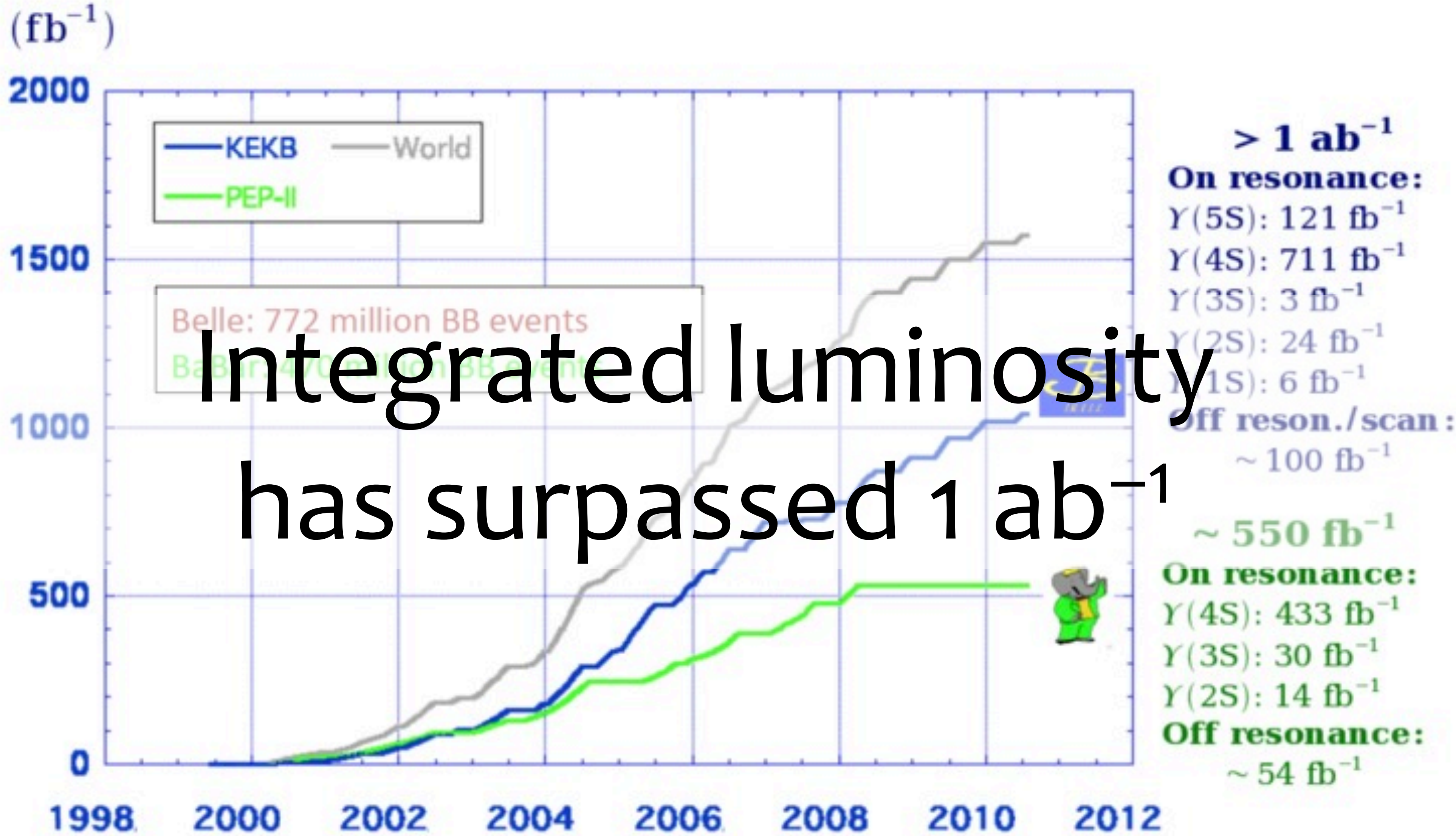
Hyodo & Oka, *PRC* **84** (2011) 034201

- Λ_c are available in Belle data
- $\rightarrow$ use Belle to determine $\pi\Sigma$ scattering length

Accumulating high quality data with the world highest luminosity for ~10 years!



Integrated luminosity has surpassed 1 ab^{-1}



- Extremely large data samples and the general-purpose character of the detector makes *B*-factory suitable place also for a study of lighter mesons/hadron physics

  - Decay of *B* mesons offer a wide phase space

  - Two-photon production channel

  - Discovery of non-$\bar{q}q$ candidates so-called *XYZ* charmonium-like states..

It‘s not appropriate to call it a byproduct

About myself

Stefan Meyer Institute for Subatomic Physics

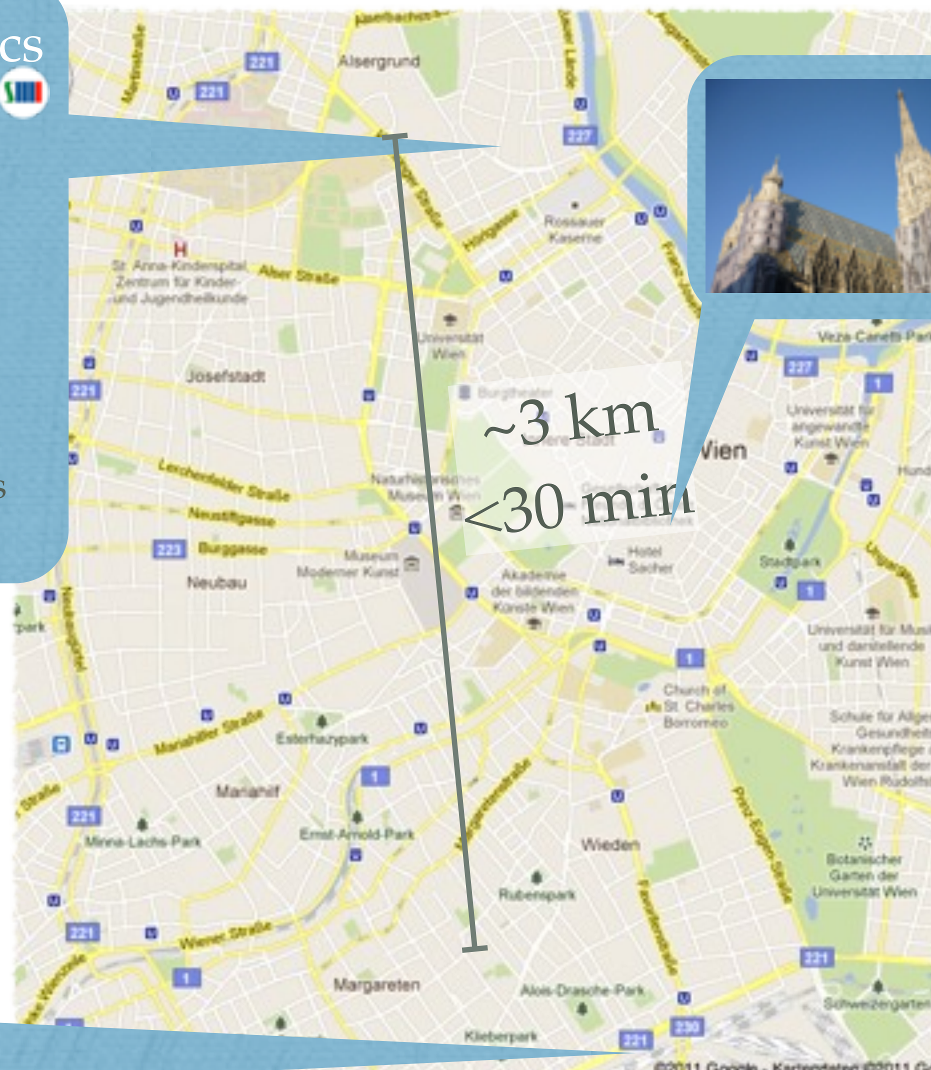
Ken Suzuki

hadron physics / exotics

Charmonium-like states / PANDA

Λ_c decay / $\bar{K}N(=\Sigma\pi)$ Interaction

Meson-Nucleon Bound States



Consortium

HEPHY

Christoph Schwanda

CKM

SVD

DAQ


NEVER GIVE UP!