A01: J-PARC KOTO実験

山中　卓

大阪大学

特定領域「フレーバー物理の新展開】研究会2012

2012年7月7日@吉野

Purpose

To search for CP Violation caused by New Physics

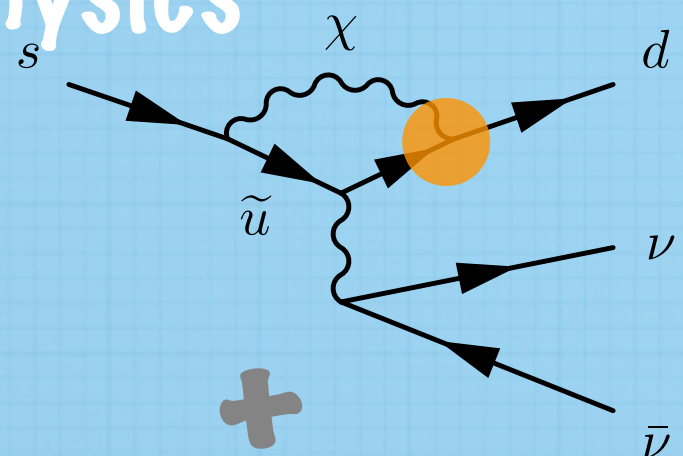
Beyond

the Standard Model

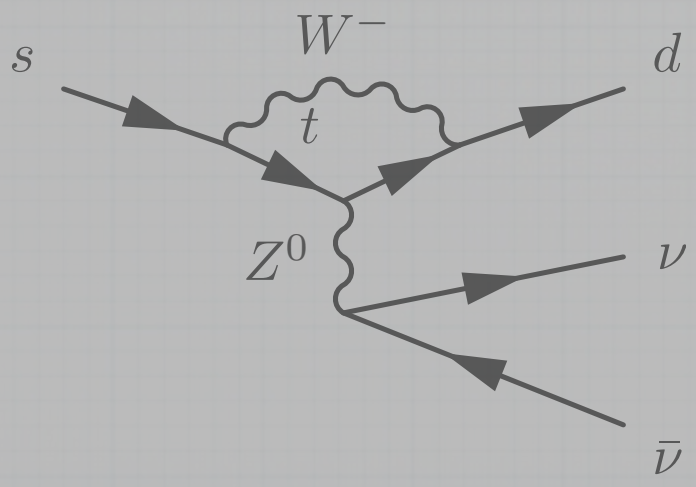
Probe: $K_L \longrightarrow \pi^0 \nu\bar{\nu}$

CP- CP+

New Physics



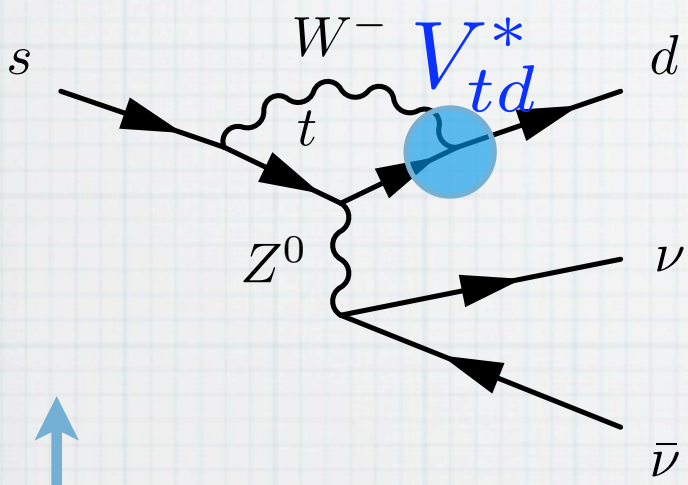
Standard Model

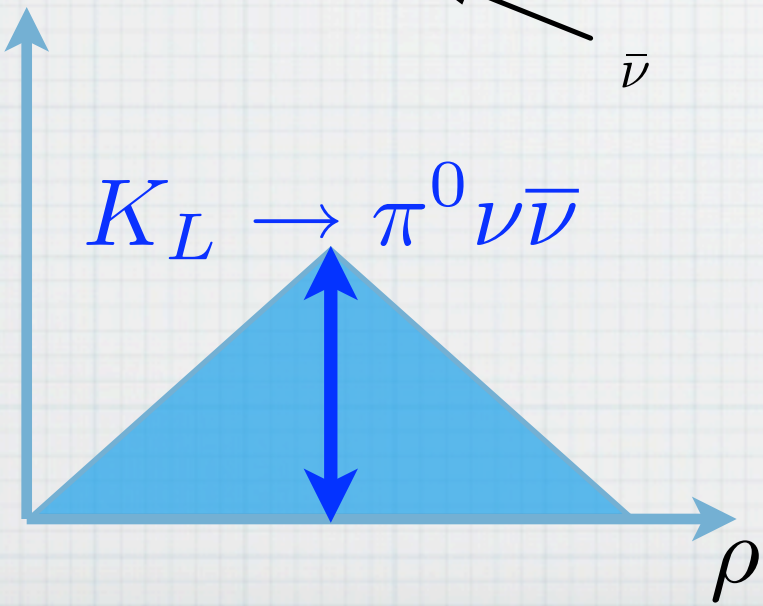


- SM background is
- small (BR~3E-11)
- well known (~2% theo. error)

$K_L \longrightarrow \pi^0 \nu\bar{\nu}$ in Standard Model

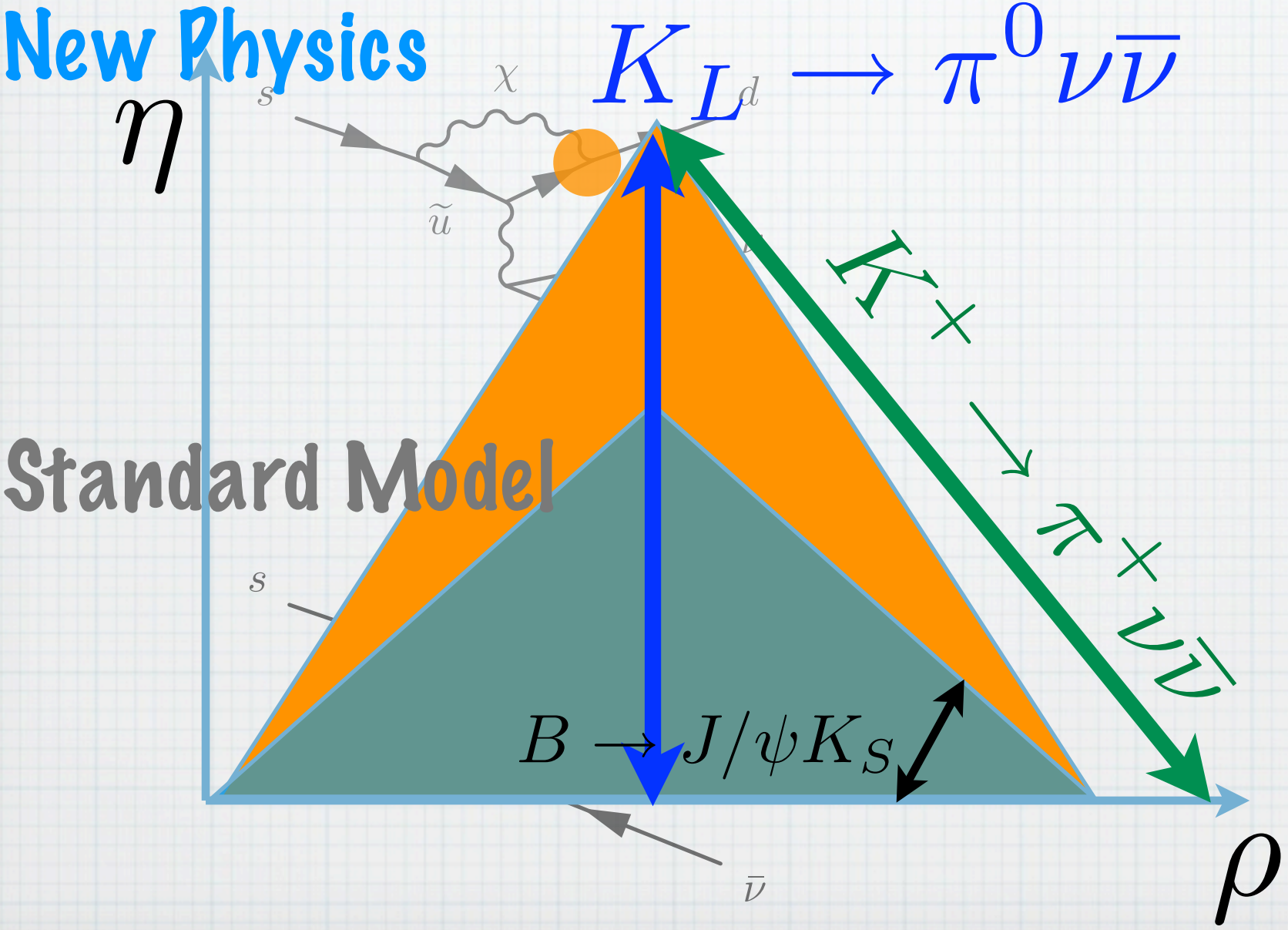
$$A(K_L \to \pi^0 \nu\bar{\nu}) \propto A(K^0 \to \pi^0 \nu\bar{\nu}) - A(\overline{K}^0 \to \pi^0 \nu\bar{\nu})$$
$$\propto V_{td} - V_{td}^*$$
$$\propto ImV_{td}$$
$$\propto \eta$$

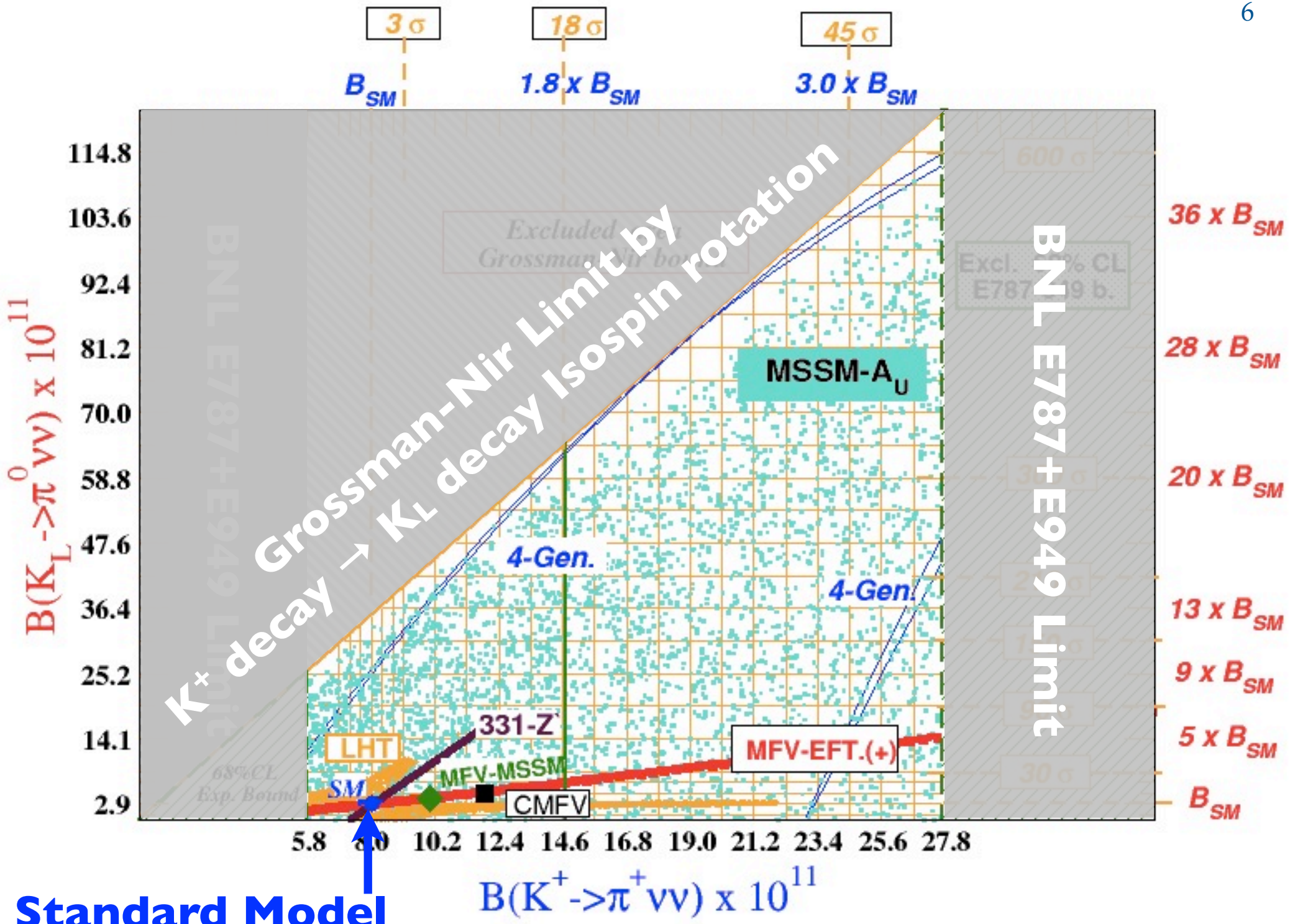




- BR = (2.8±0.4) x 10^{-11} (w/currently known CKM parameters)
- 1 - 2% theoretical error

In terms of CKM matrix parameters



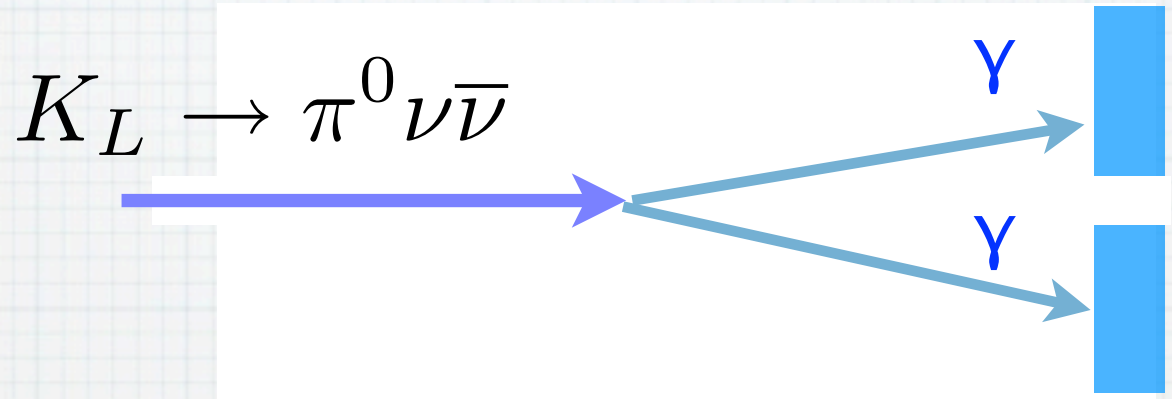


Standard Model

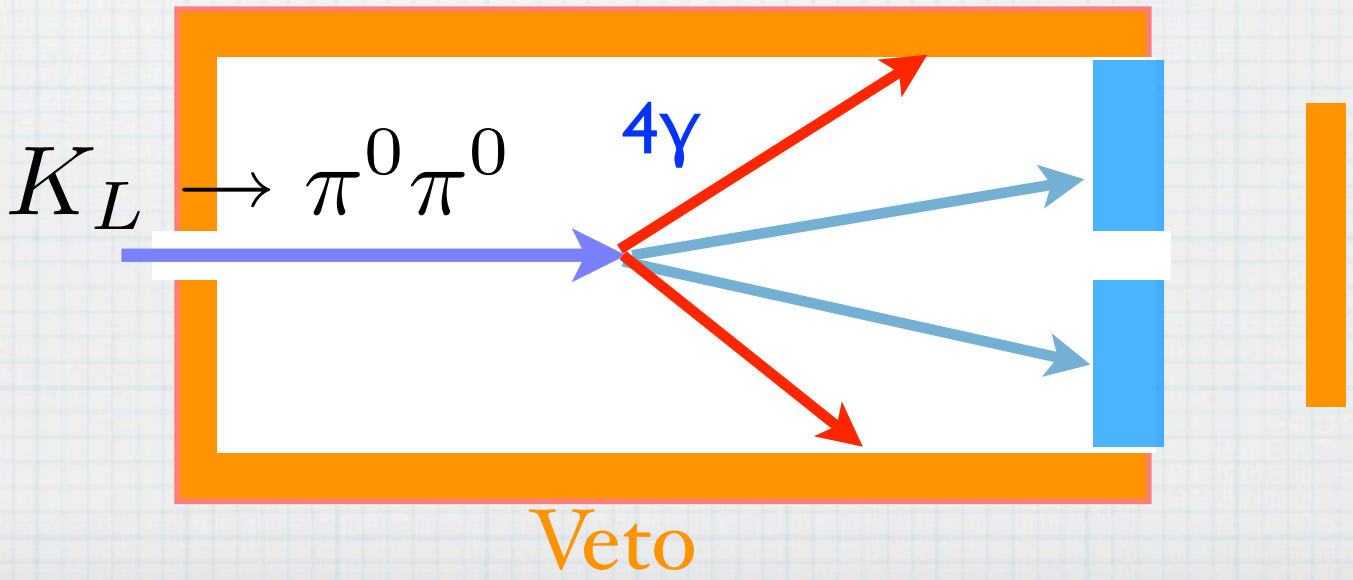
http://www.lnf.infn.it/wg/vus/content/Krare.html

Signal and Background

* Signal:



* Background



koto_icepp_symposium_2012-02 — Locked

New Play View Themes Masters Text Box Shapes Table Comment Group Ungroup Front Back Mask Inspector Media Adjust Colors Font

Slides

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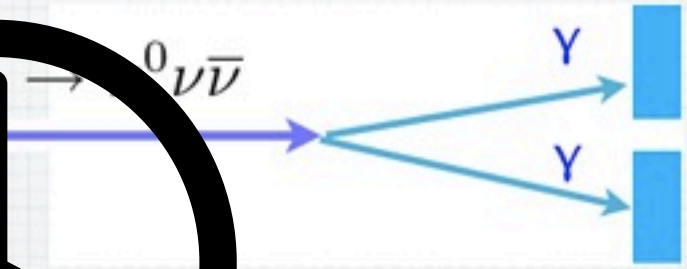
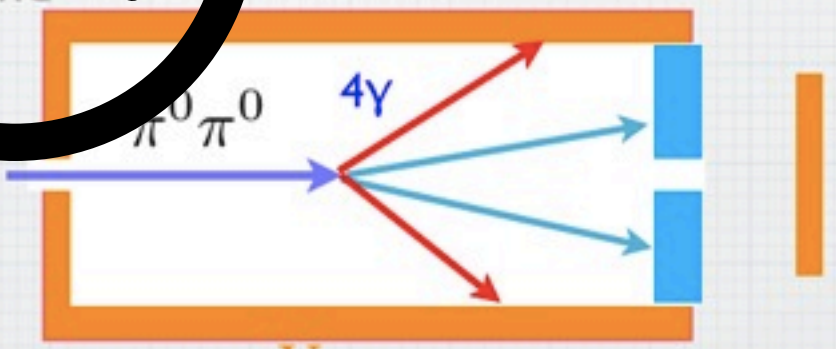
Signal and Background

* Signal: $K_L \to \pi^0 \nu\bar{\nu}$



* Background



100%

My first encounter

* 1988 Snowmass, Colorado

Proceedings of the Summer Study on High Energy Physics in the 1990s

June 27 – July 15, 1988
Snowmass, Colorado

KAON PHYSICS IN THE 1990s: RARE DECAYS AND CP VIOLATION

M. Atiya, E. Blackmore, G. Bock, D. Bryman, M. Cooper, H. Gordon,
L. Littenberg, W. Louis, H. Lubatti, K. McFarlane, K. Nishikawa,
J. Ritchie, L. Roberts, T. Shinkawa, M. Sivertz, A. J. S. Smith,
G. Thomson, R. Tschirhart, T. Yamanaka

PRD VOLUME 39, NUMBER 11

CP-violating decay $K_L^0 \to \pi^0 \nu\bar{\nu}$

Laurence S. Littenberg

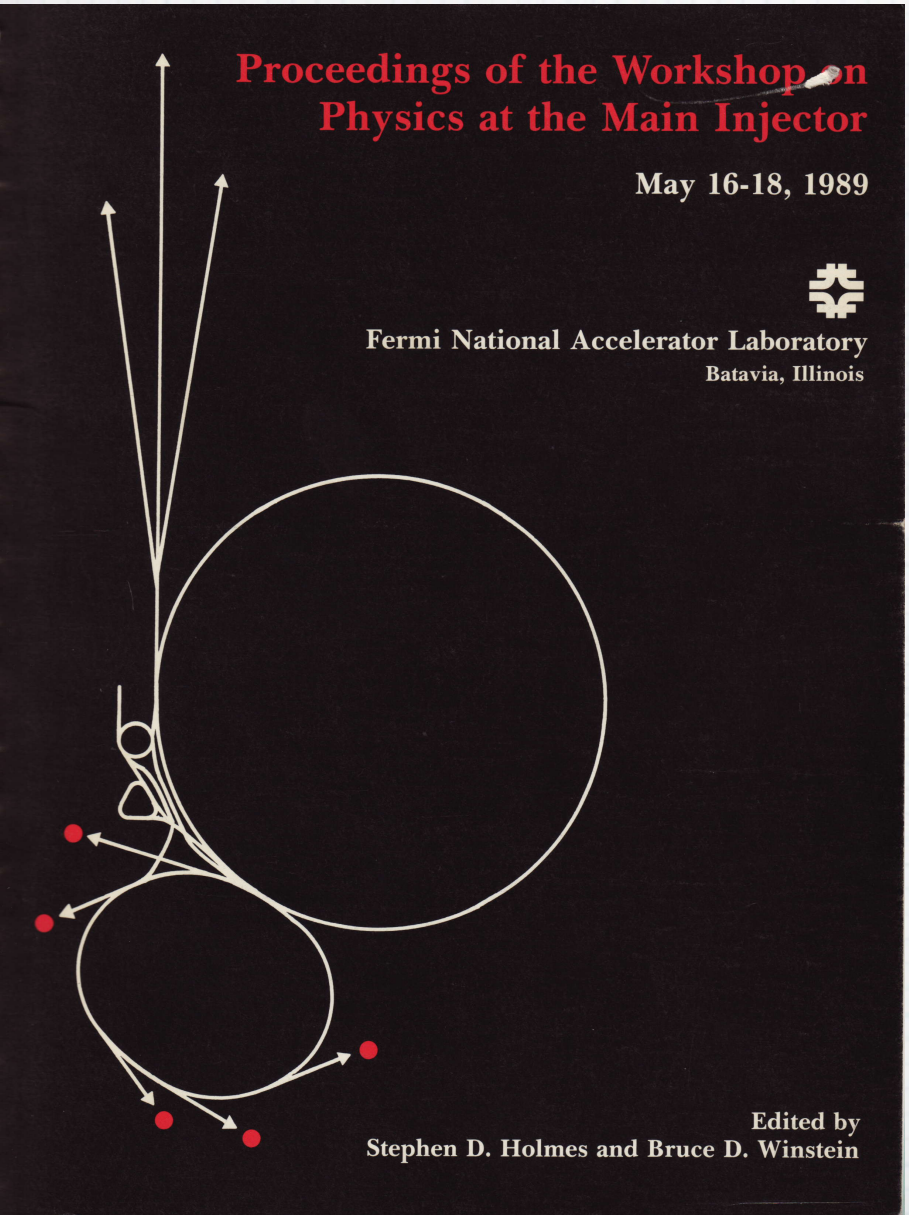
A new possibility

One of us has pointed out [24] that the decay $K^0_L \Rightarrow \pi^0 \nu\bar{\nu}$ affords a very new interesting opportunity in K decay. This decay has never been actively sought, and the Standard Model prediction is of the order of a few x 10^{-12}, leaving a huge window for new physics.

now proposed. Although this measurement is extremely difficult, its ratio of interest/-difficulty seems to us to compare favorably to that of making detailed CP-violation studies in B-decay.

New facilities [25] at which K physics can be pursued have been proposed or at least discussed by LANL (AHF), TRIUMP (KAON), BNL (AGS II), A European consortium (HEP), KEK (JHF), and INR Moscow.

My second encounter

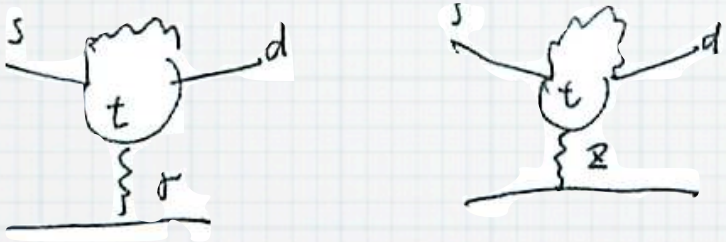


* 1989 Main Injector Workshop@Fermilab

5/16/89 Main Injector Work shop

F. Gilman

If $M_t > M_W$



$K_L \to \pi^0 \nu\bar{\nu}$ 1

m_t^2/M_Z^2 ⇒ comparable ?

No 2γ

As m_t ↑ : one loop has more physics

indirect CP negligible

no EM penguin

⇒ Direct CP from C

BR = $O(10^{-11})$

PROSPECTS IN K PHYSICS*

Frederick J. Gilman

$$B(K_L^0 \to \pi^0 \nu_\ell \bar{\nu}_\ell) \approx 2.1 \times 10^{-5} (s_2 s_3 s_\delta)^2 \, |\tilde{C}_{\nu,t} - \tilde{C}_{\nu,c}|^2$$

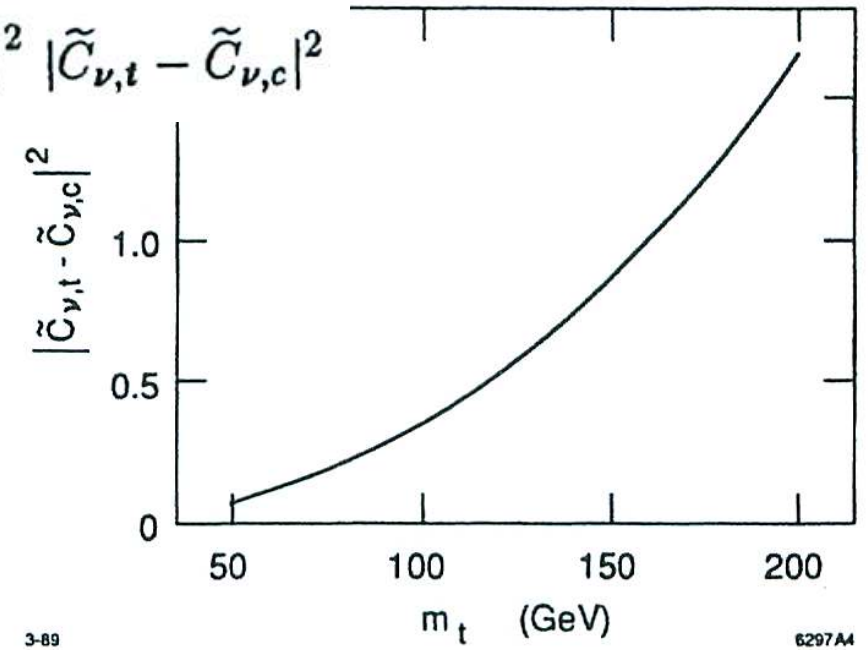


Fig. 8. The quantity $|\tilde{C}_{\nu,t} - \tilde{C}_{\nu,c}|^2$, which enters the branching ratio for the CP violating decay $K_L \to \pi^0 \nu_\ell \bar{\nu}_\ell$, as a function of m_t. From Ref. 26.

Experimentally, the problems are perhaps best represented by the statement that nobody has yet shown that a measurement of this decay is absolutely impossible.

My third encounter

* May? 1990: Bruce Winstein cornered me in ...

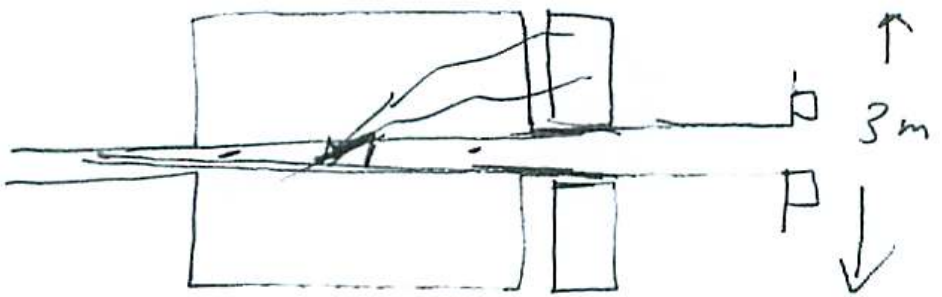
$K_L \to \pi^0 \nu\bar{\nu}$

① $BR = 1.0 \times 10^{-12} \left(\frac{f_B}{100\,MeV}\right)^2$, independent of m_t, η, V_{td}, ...

vector decay, like K_{e3}

② $\Rightarrow$ need 10^{-13} sensitivity exp

③ If at AI, $\langle p \rangle \simeq 5\,GeV$



$\frac{2\,cm}{30\,m} \times 5\,GeV \simeq 4\,MeV$

④ Need 5cm x 5cm beam @ 30m w 3×10^{13}/pulse

$\Rightarrow$ 10 MH$_2$ g K decays / 20m 300 MH$_2$ g hadrons

guess: 20% acceptance $\pi^0 > 100$ MeV/c P_T

$\Rightarrow$ 10^{-13} / 5000 hits

Ⓐ Acceptance for this geom, $P_T > 100$; > 140 ; > 210
-2 acceptance

Ⓑ Spectrum accepted γ's
" " γ's hitting veto from $2\pi^0$, $3\pi^0$ (what do they go)
" " $\pi^\pm$ " " " " $\pi^+\pi^-\pi^0$ decay

Ⓒ Down the hole(s)?
rate of $2\pi^0$, $3\pi^0$ with 2, 4 missing

66

6/3/90 $K_L \to \pi^0 \nu \bar{\nu}$

UMINN. INPUT

UMINN. OUT/HIST.

Gen $1 < p < 50$

$25 < z < 45$ m

EGCUT = ∅

Ethr @ glas = 1GeV

#gen 100k

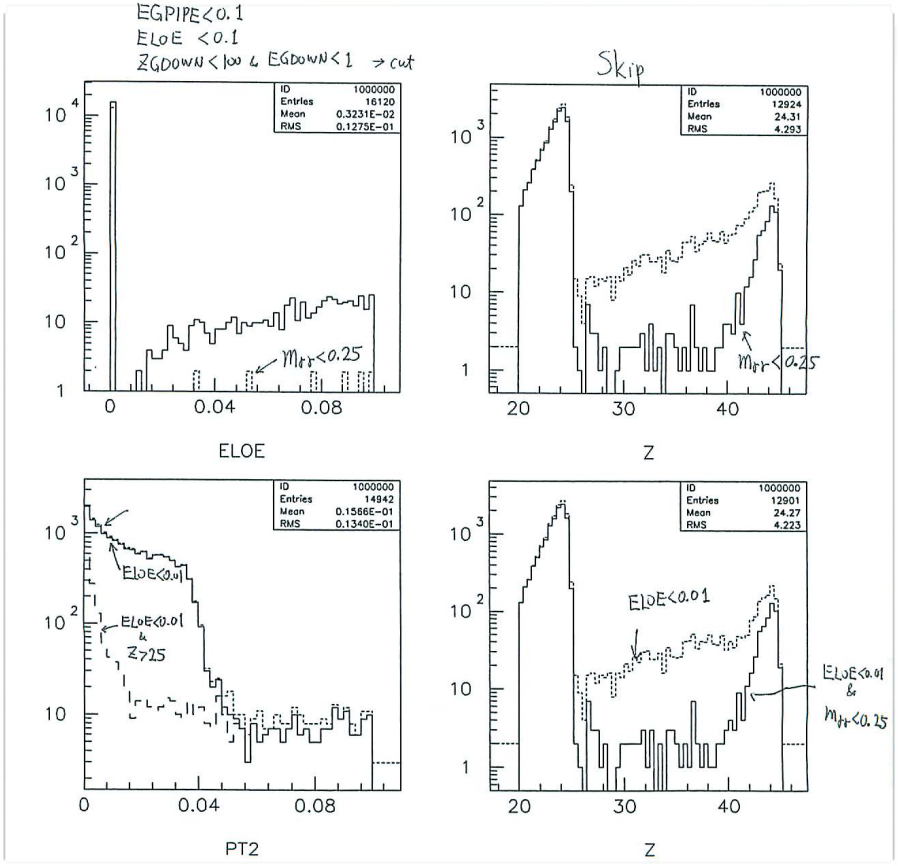
#acc (nppby=2) 23.1k

80 lowE cluster ($2\pi^0$)

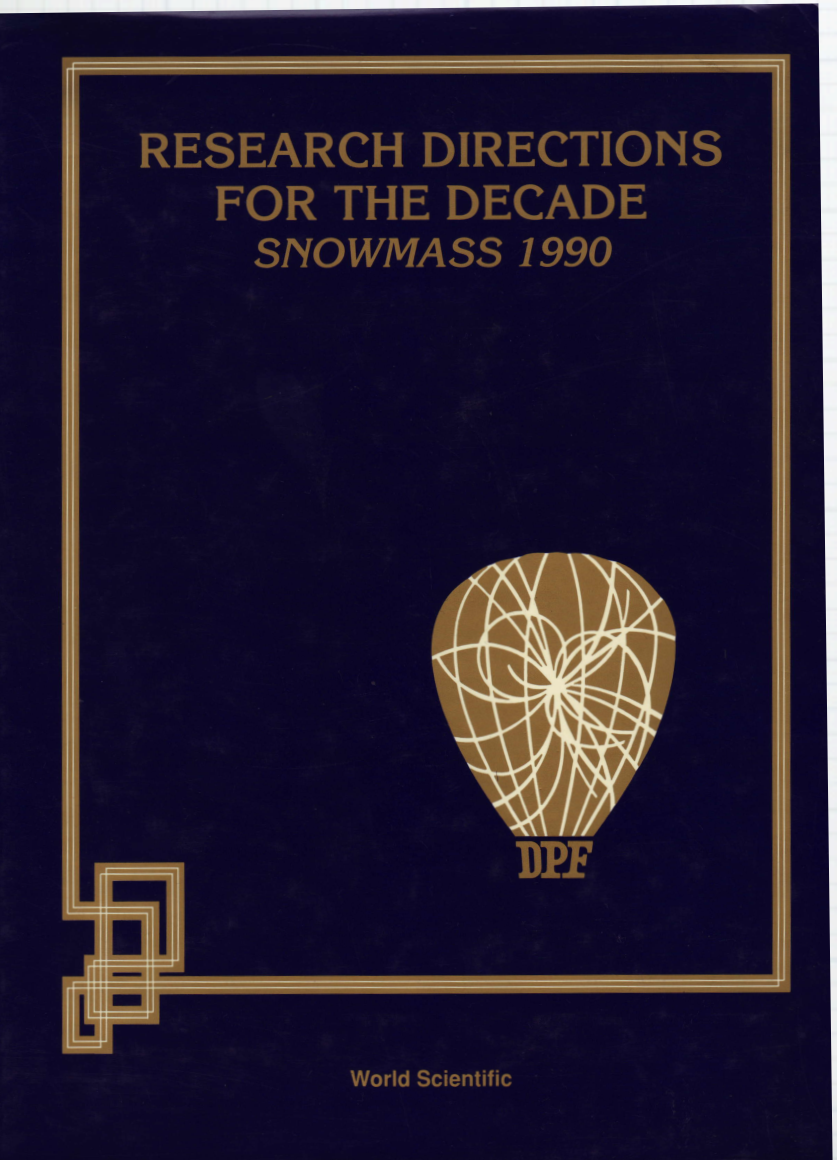
UMI2PIφ6

E_{lowE} cones down to 10MeV.

Reducing ElowE cut from 0.1 → 0.01 GeV makes small differ.

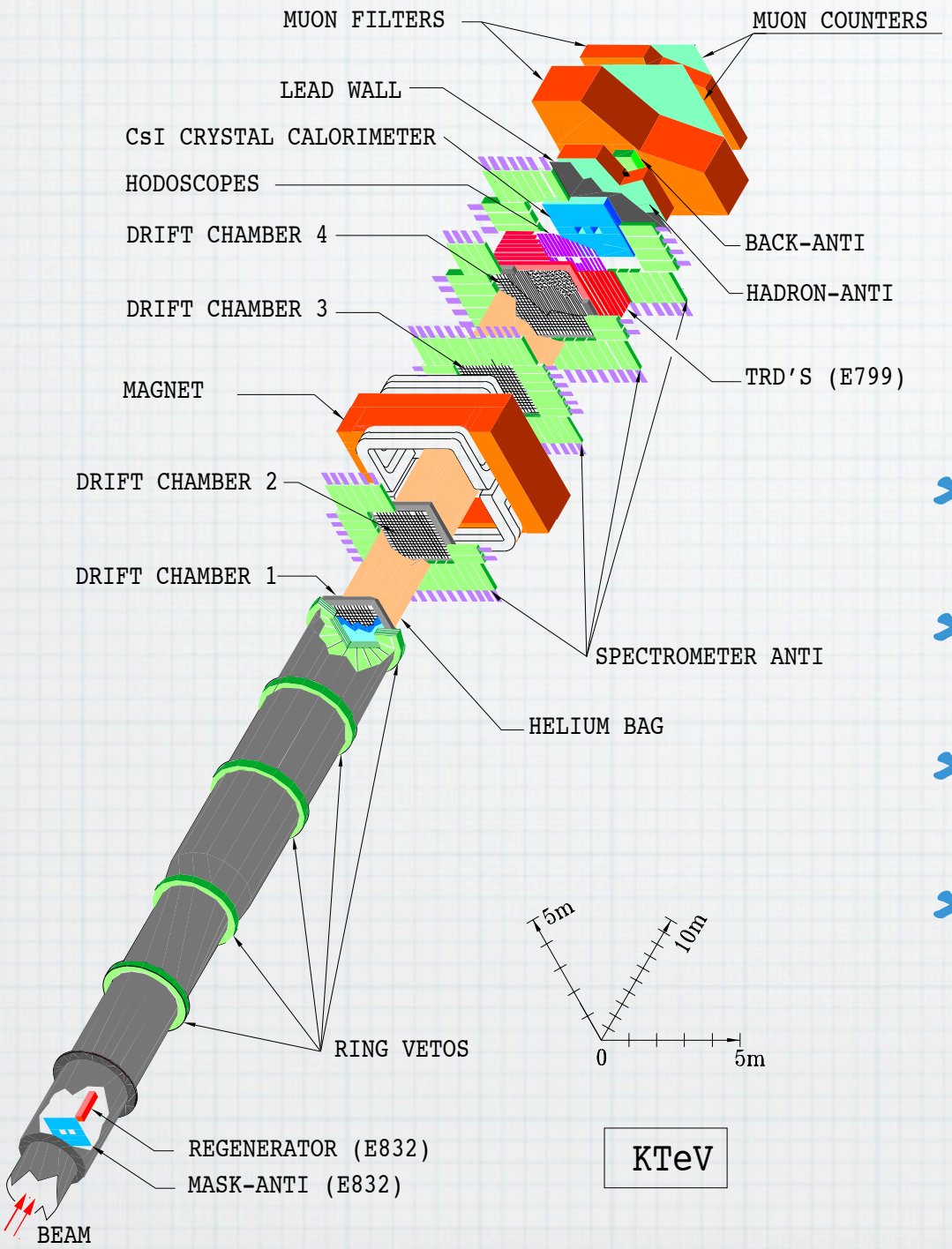


Snowmass 1990: Main Injector as K factory



* Use high intensity 120GeV protons for
* $\varepsilon'/\varepsilon < 10^{-4}$
* $K_L \to \pi^0 ee, \pi^0 \mu\mu$
* $K_L \to \pi^0 \nu\bar{\nu}$ ~10^{-12}
* Made 176 page KAMI Conceptual Design Report

Fermilab KTeV

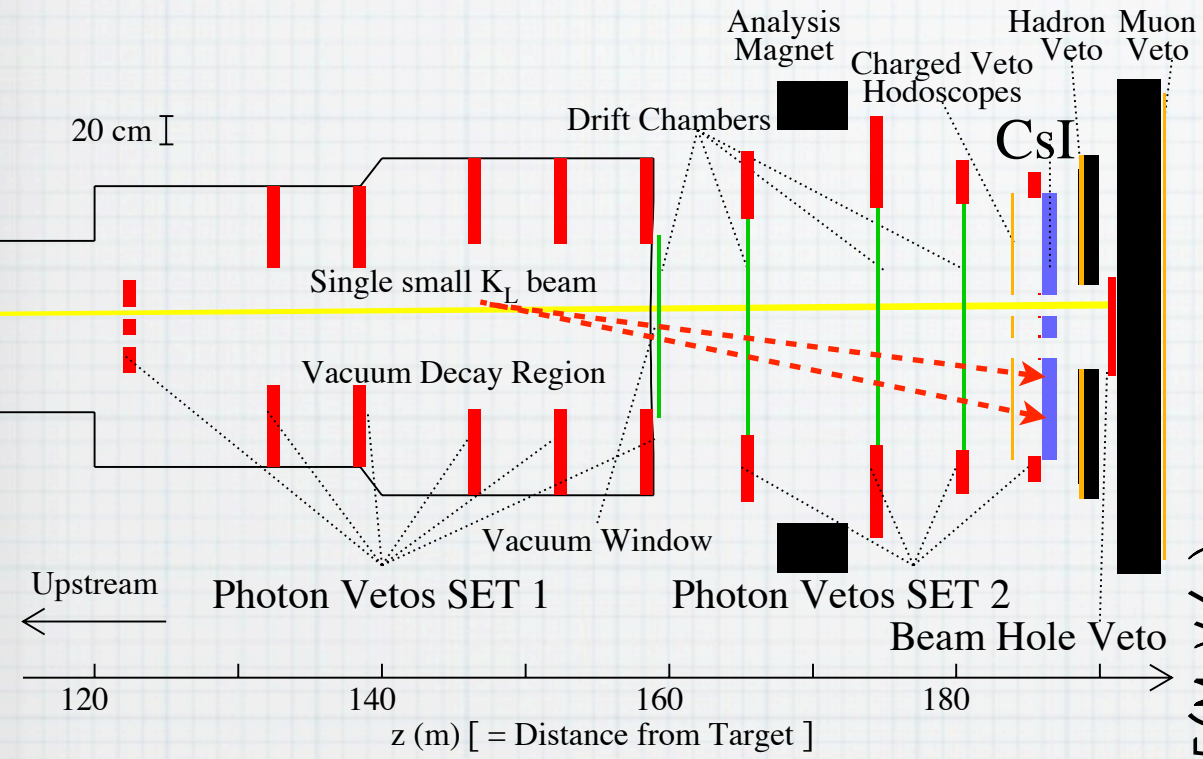


* 800GeV protons
* ran 1996-2000
* ε'/ε : KM or ~~Superweak?~~
* many rare KL decays

$$K_L \to \pi^0 ee, \pi^0 \mu\mu,$$
$$\pi^+\pi^- ee,$$
$$ee\gamma, \mu\mu\gamma, \ldots$$

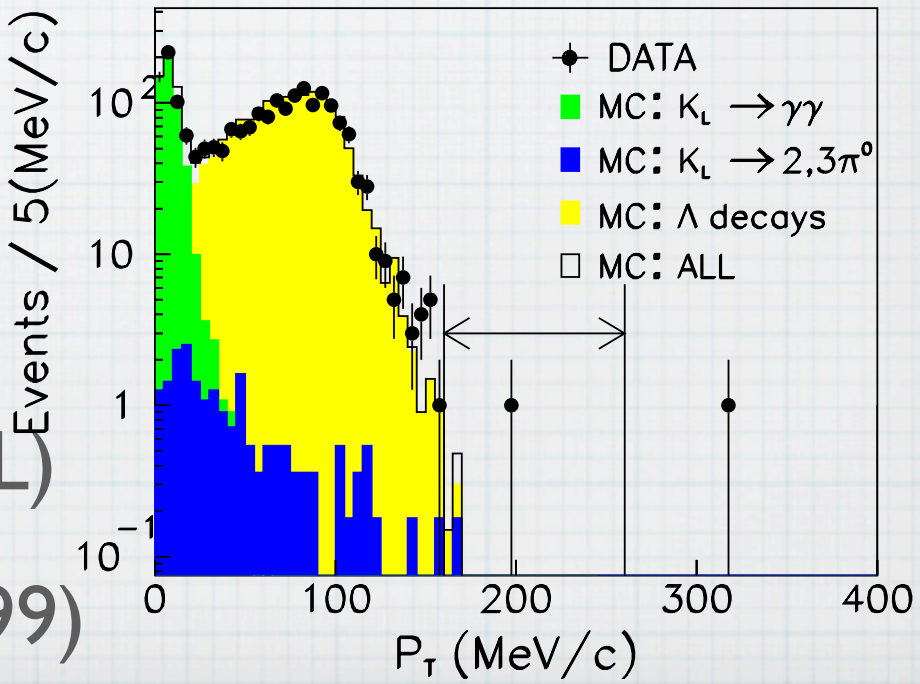
KTeV $K_L \to \pi^0 \nu\bar{\nu}$

$\hookrightarrow \gamma\gamma$



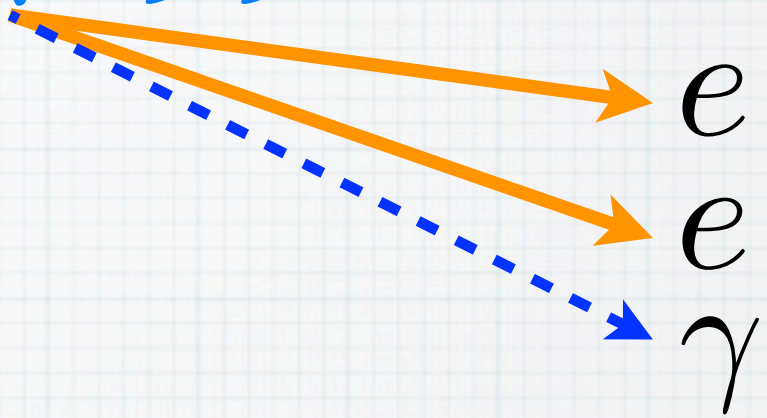
Assume $m_{\gamma\gamma} = m_{\pi^0}$

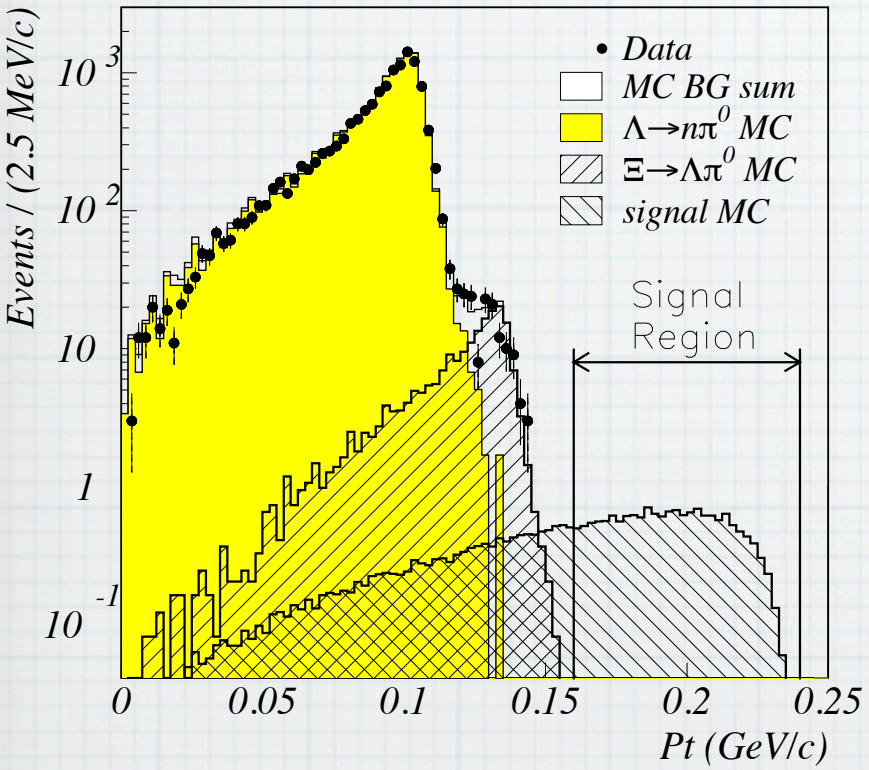
Calc. z-vertex, and transverse momentum of π^0



- 1-day special run
- BR < 1.6 x 10^{-6} (90% CL)
- Phys. Lett. 447, 240 (1999)

KTeV $K_L \rightarrow \pi^0 \nu\bar{\nu}$





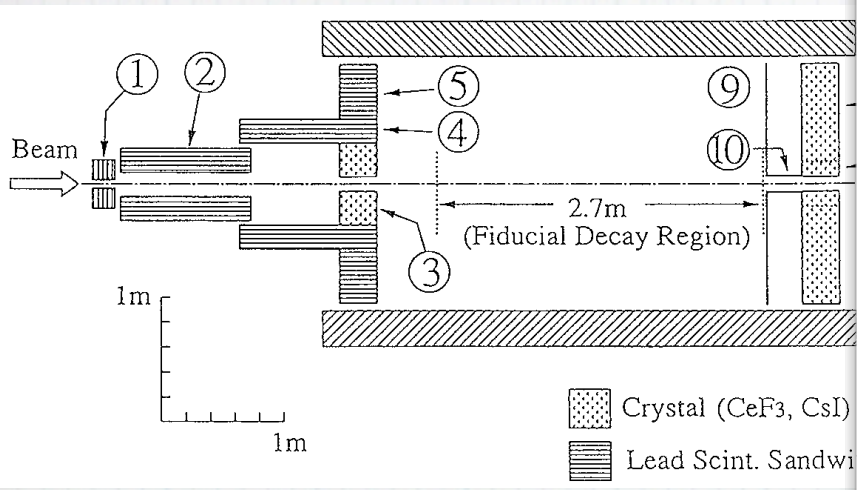
- can reconstruct

  z-vertex, π^0 mass, Pt

- BR < 5.9×10^{-7}

- Phys. Rev. D61, 072006 (2000)

KEK E391a



* Inagaki
* 12GeV KEK PS
* Goal: 3×10^{-10}

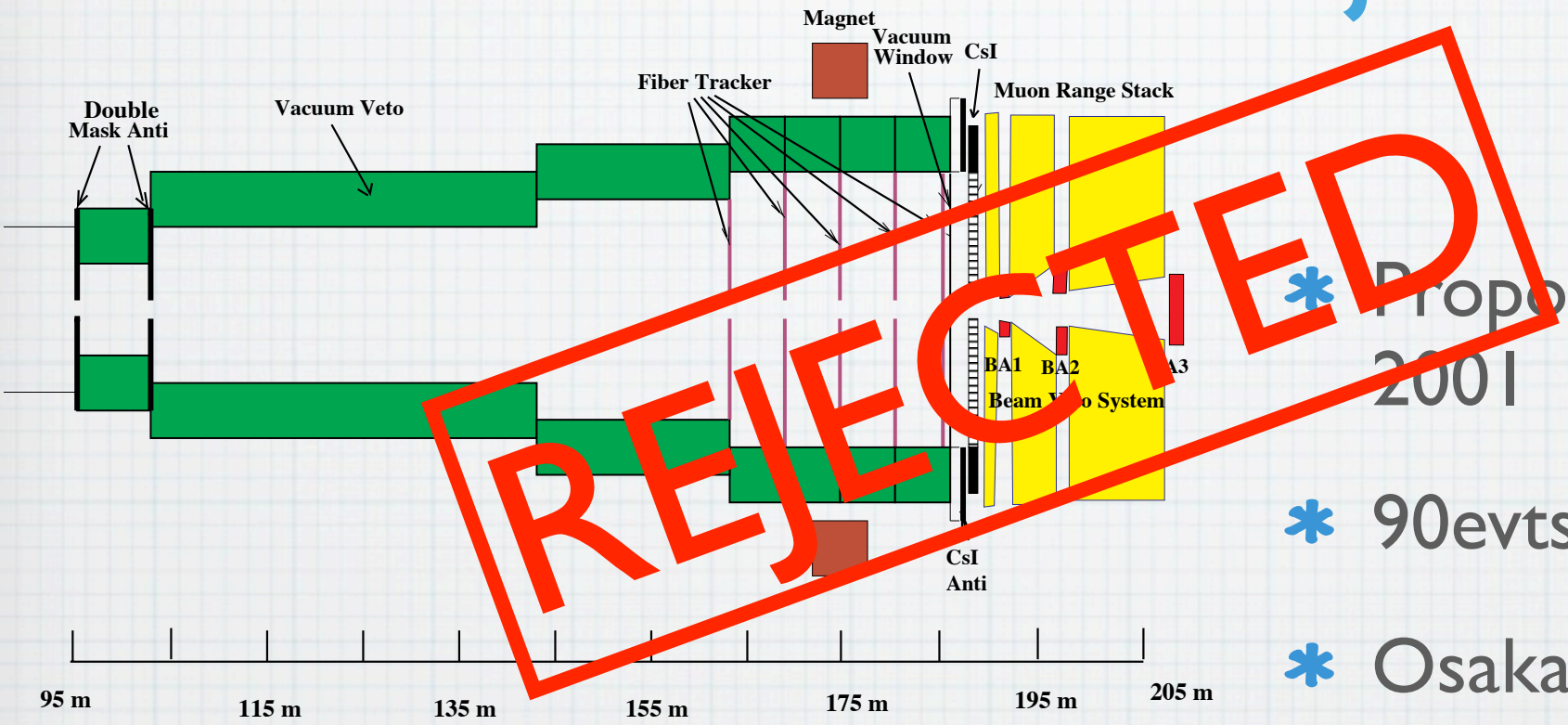
KEK E391A Review

久野良孝、笹尾登、山中卓

2001 年 4 月 11 日

* 目的の感度は達成？ Yes
* 将来につながる？ Yes
* 2億円で建設できる？ No
* 2年で建設できる人員？ No

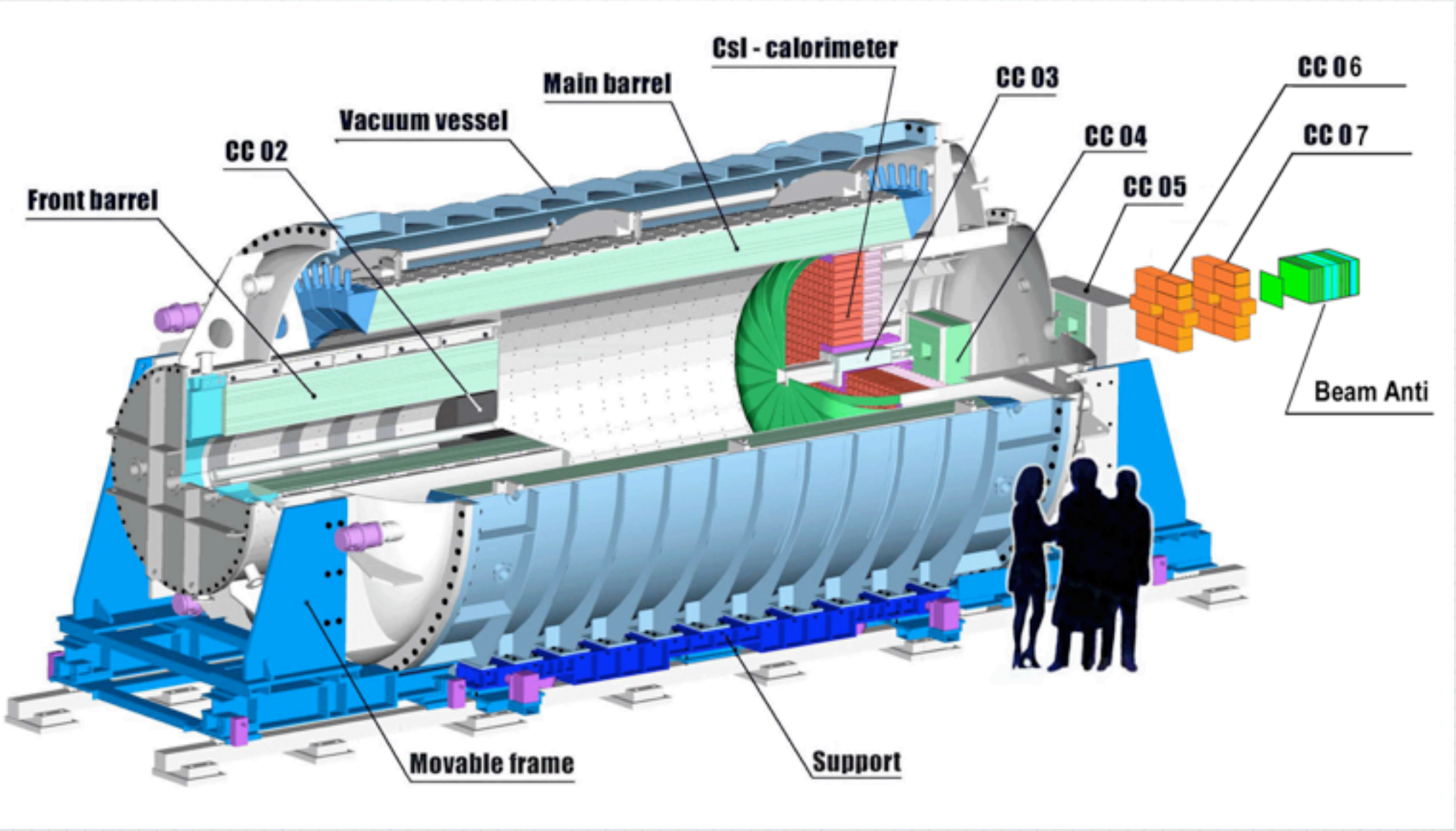
Fermilab KAMI: KAons at Main Injector



REJECTED

* Proposed in Apr. 2001
* 90evts/year
* Osaka Univ

2001: Joined E391a

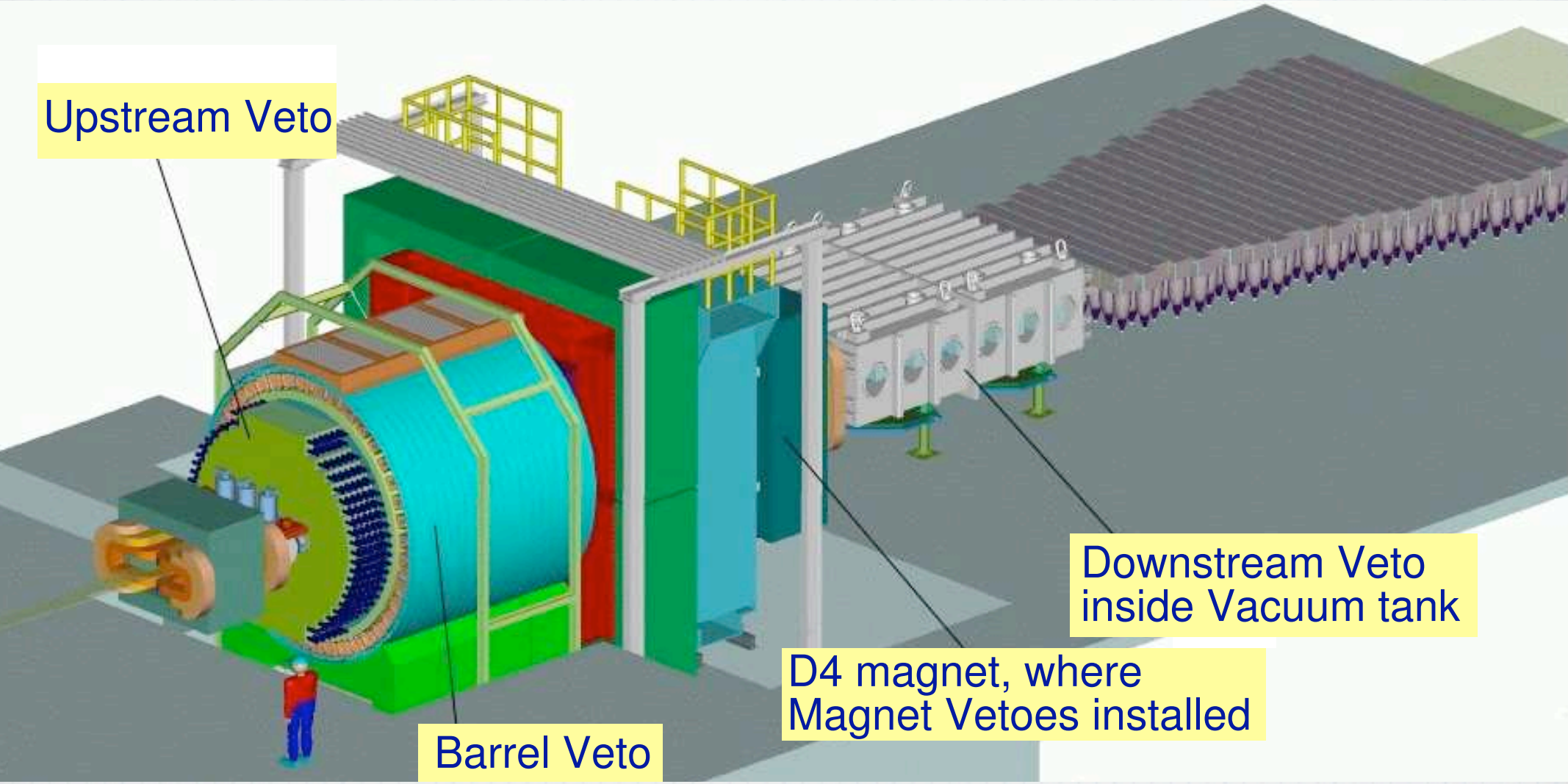


特定領域

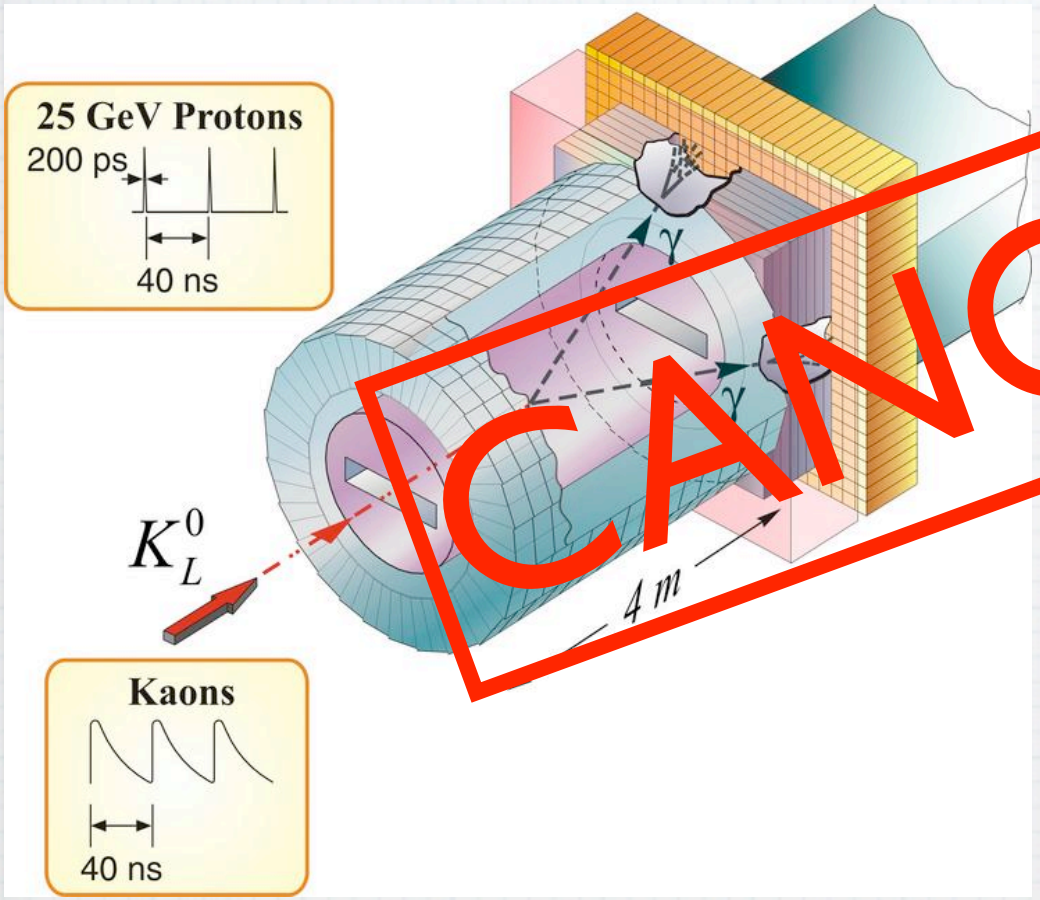
質量起源と超対称性物理の研究

* 領域代表：金 信弘
* 2001 ~ 2005
* CDF, Belle, Theory
* E391a: 3.5億円
* BNL 787/949 ($K^+ \to \pi^+ \nu\bar{\nu}$), KOPIO ($K_L \to \pi^0 \nu\bar{\nu}$)

BNL KOPIO

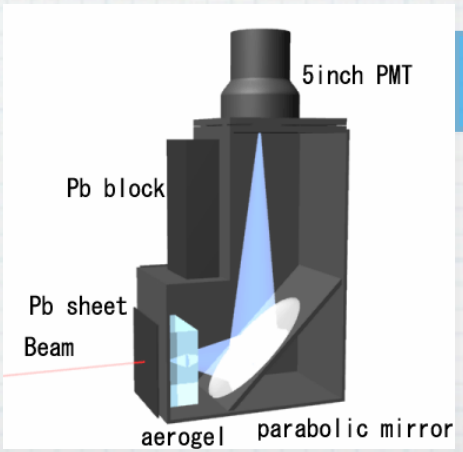

Upstream Veto
Downstream Veto
inside Vacuum tank
D4 magnet, where
Magnet Vetoes installed
Barrel Veto

BNL KOPIO



CANCELED

* 0.65GeV/c K_L
* Use Kaon TOF to constrain kinematics
* ~200 evts
* Kyoto group

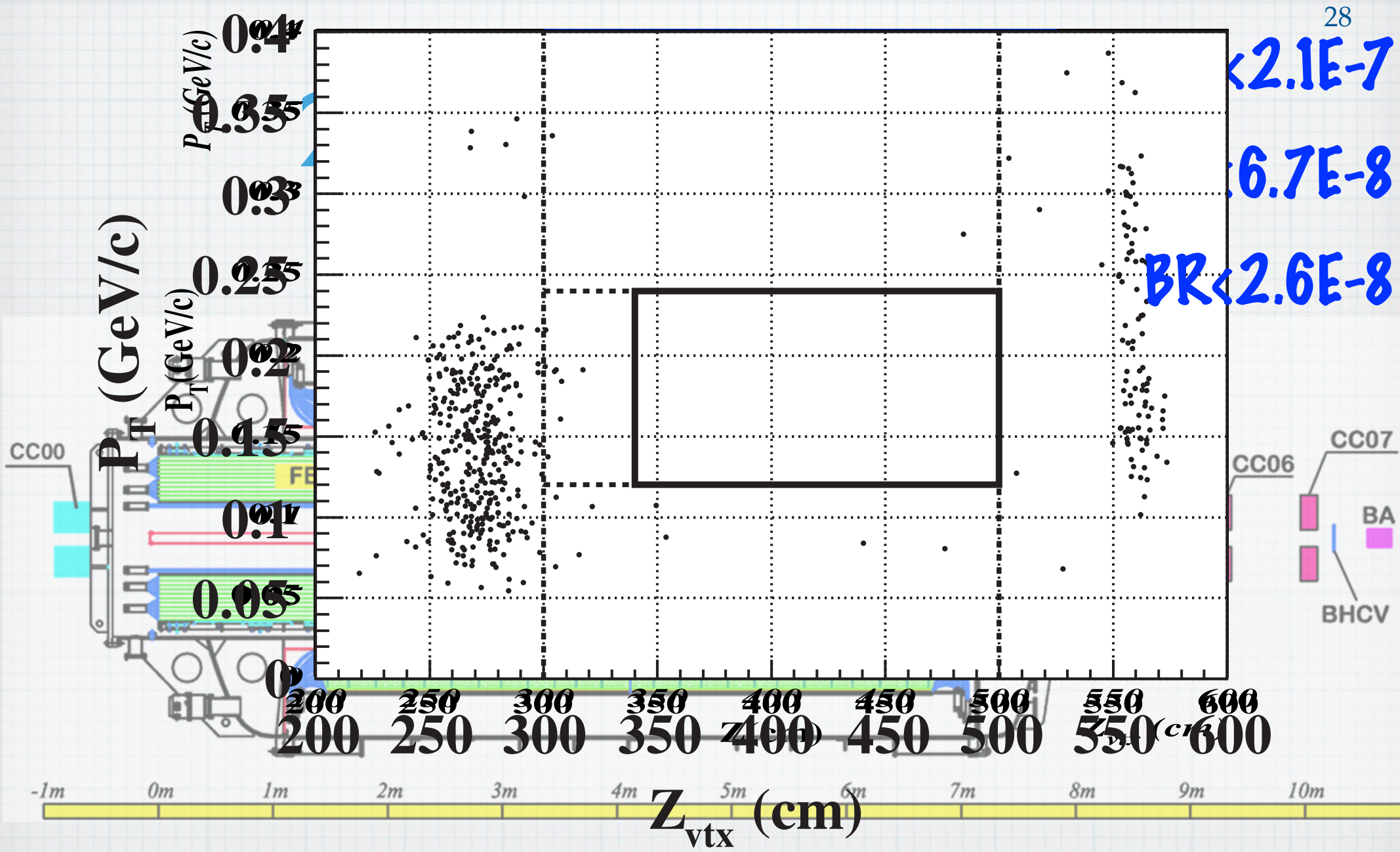


KEK E391a

OK * 予算：＋特定領域

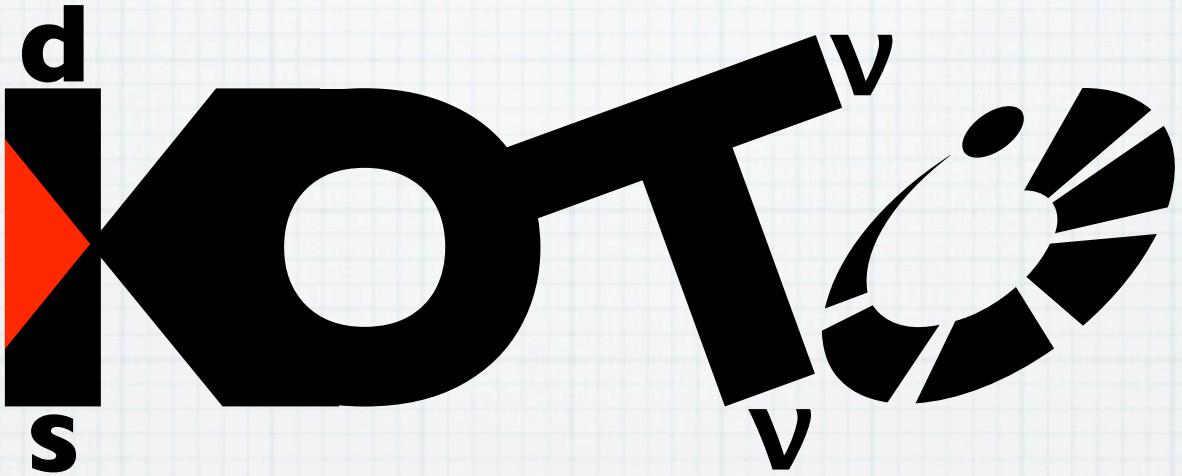
OK * 人員：＋阪大 + Chicago (KAMI)

＋京大(KOPIO)


P_T (GeV/c)
Z_{vtx} (cm)
CC00
CC06
CC07
BA
BHCV
FE
-1m
0m
1m
2m
3m
4m
5m
6m
7m
8m
9m
10m

BR<2.1E-7
BR<6.7E-8
BR<2.6E-8

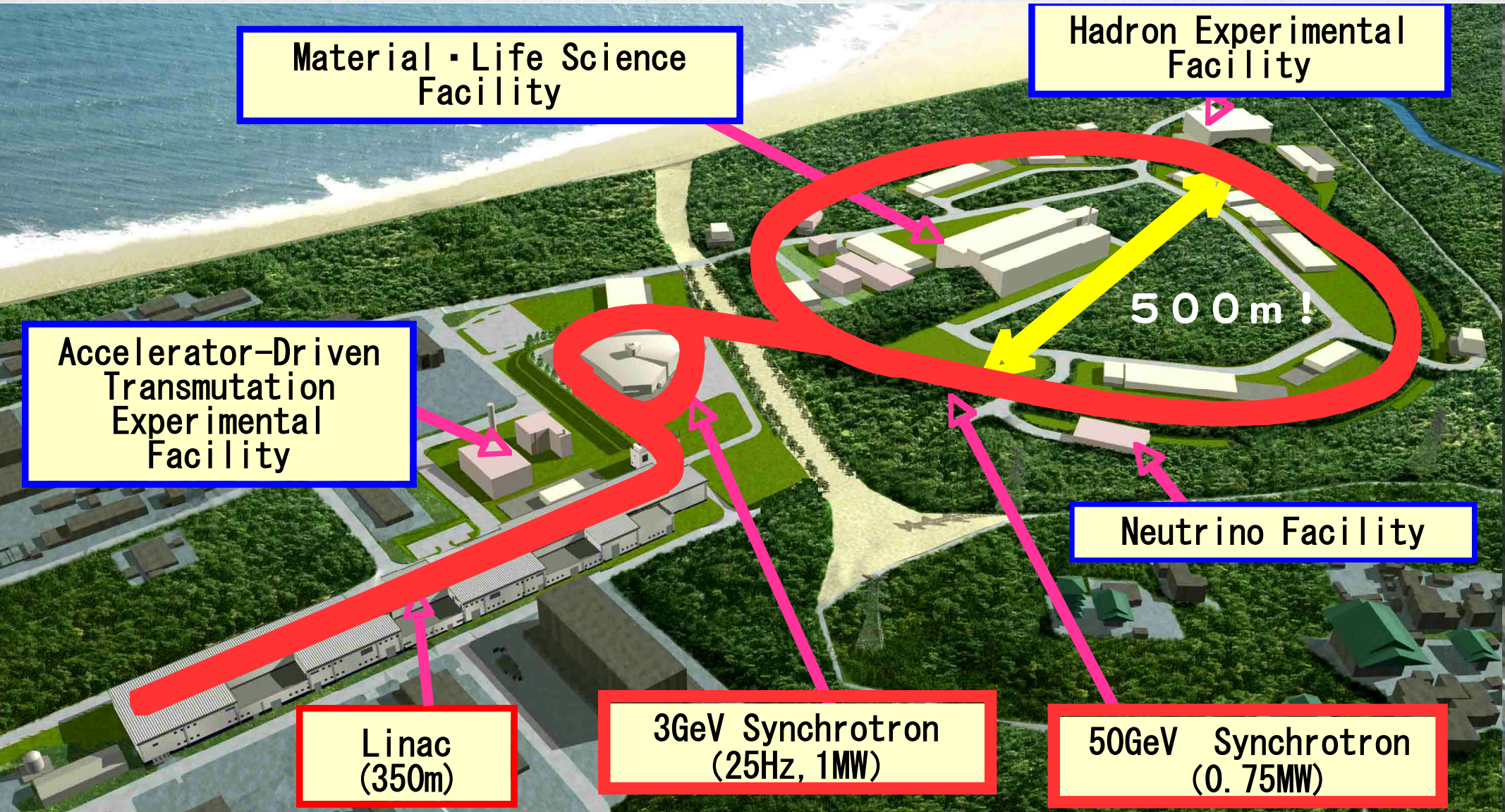
J-PARC E14



= K^0 at TOkai

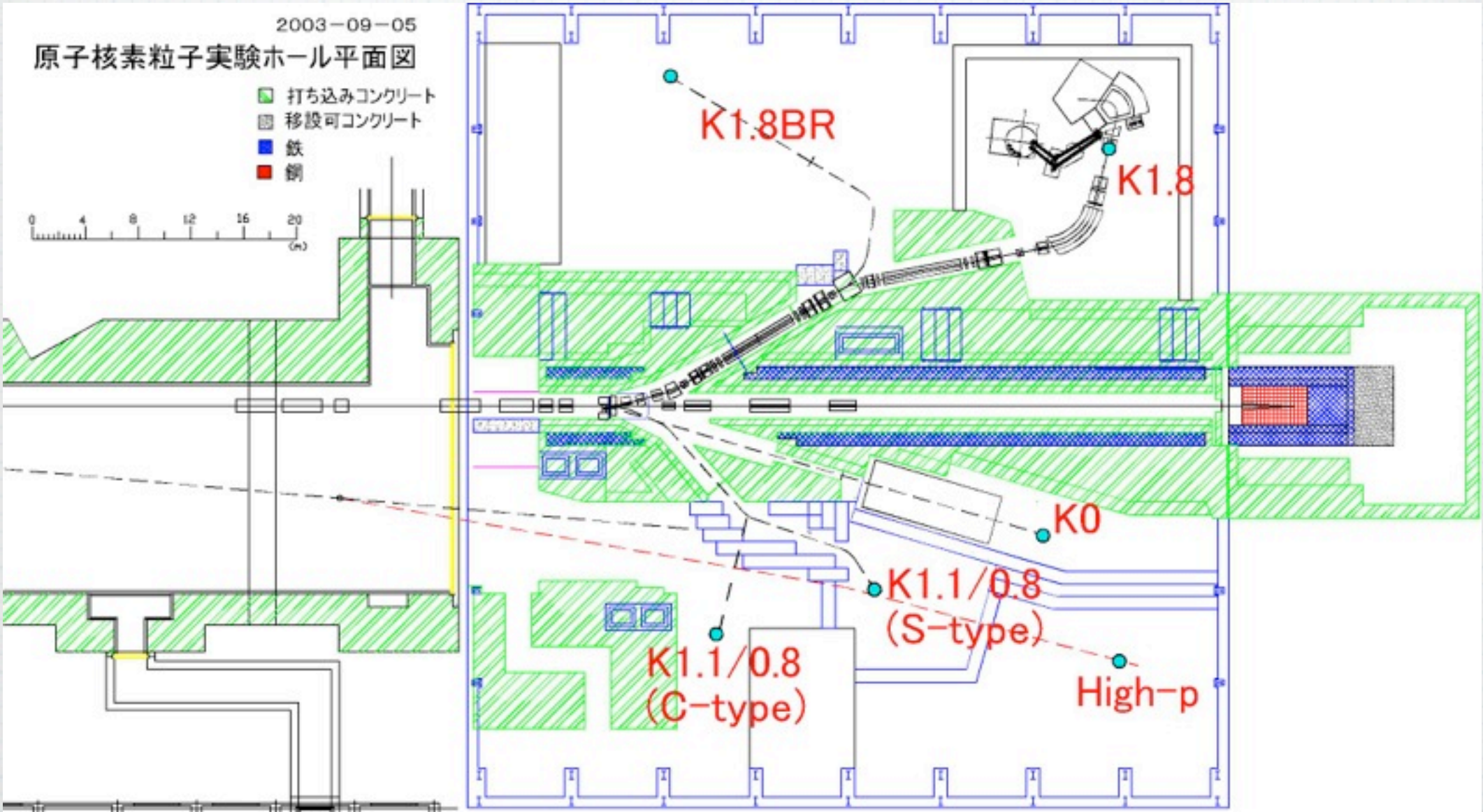
Arizona State, Chicago, CNU, JINR, KEK, Kyoto, Michigan, NDA, NTU, Osaka, Pusan, Saga, U.Seoul, Yamagata

Japan Proton Accelerator Research Complex

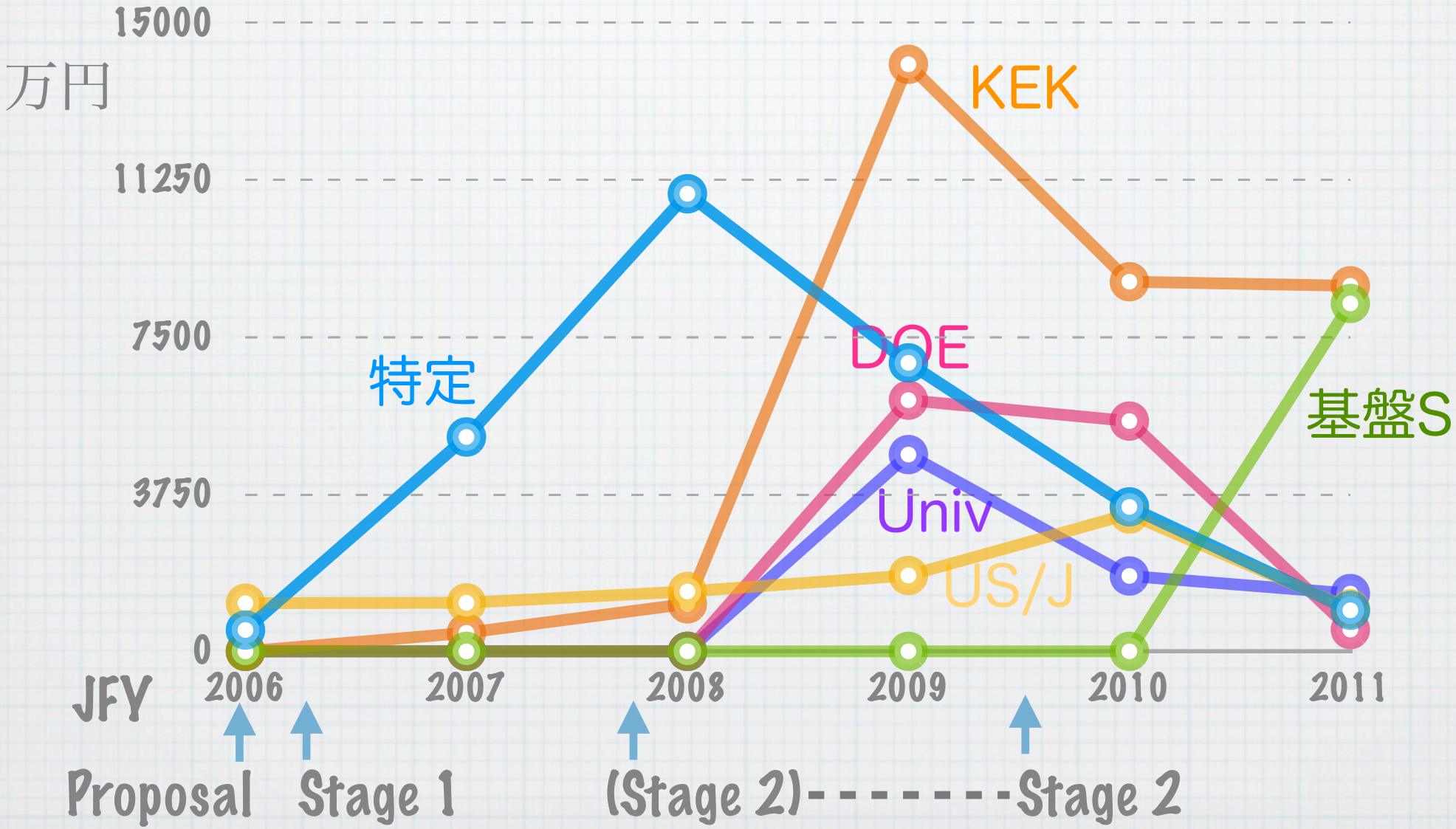



Slow Extraction
© 2011 ZENRIN
© 2011 Geocentre Consulting
1/3/28
2003
36°26'49.88" N 140°36'14.66" E 標高 10 m

Experimental Hall



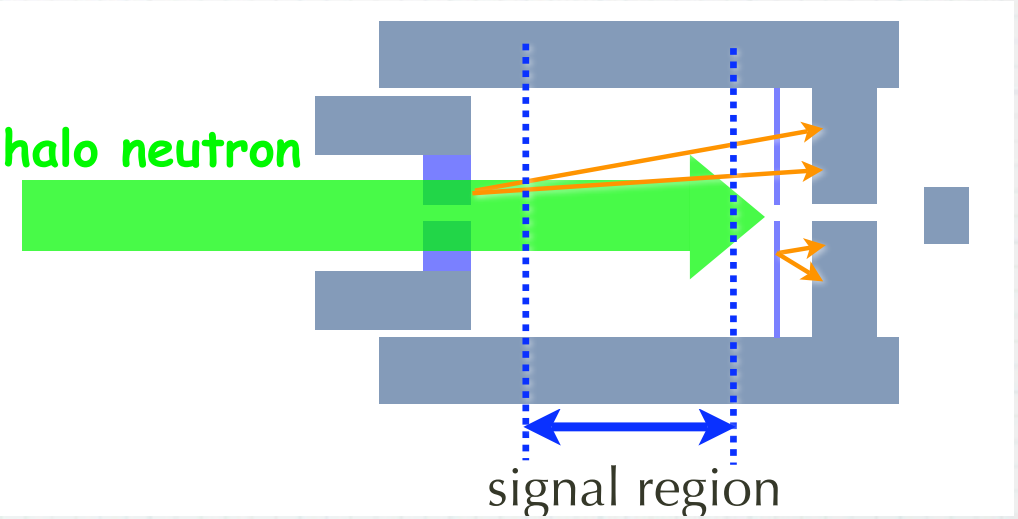
"Flavor Physics" Tokutei



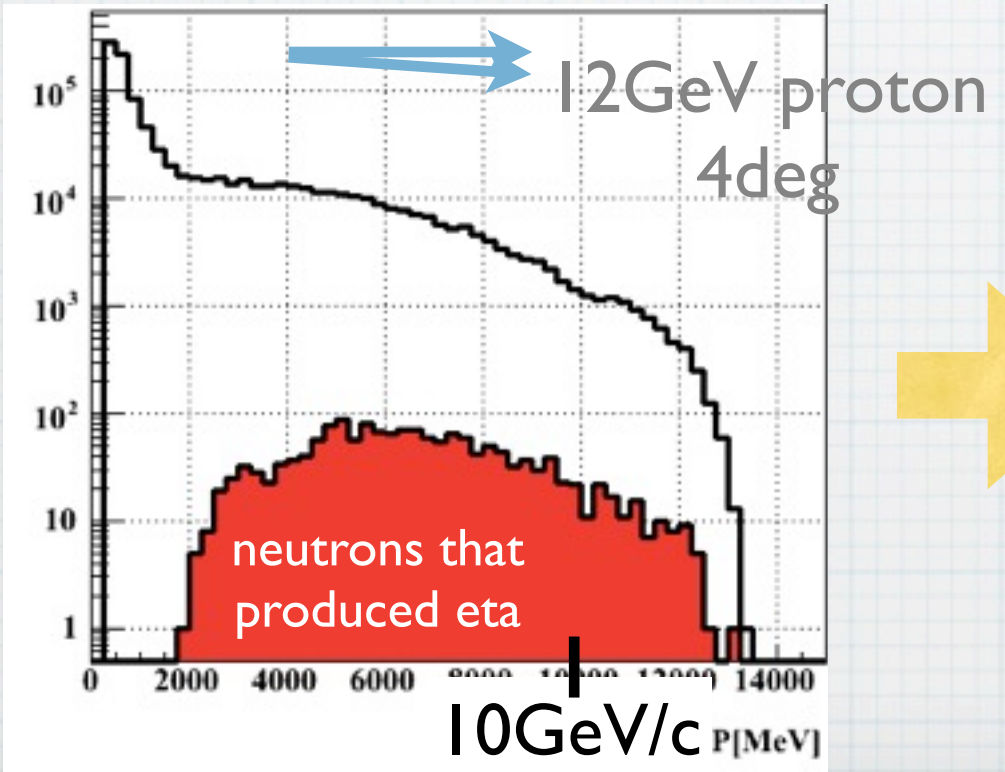
K_L Beamline

Softer neutron momentum

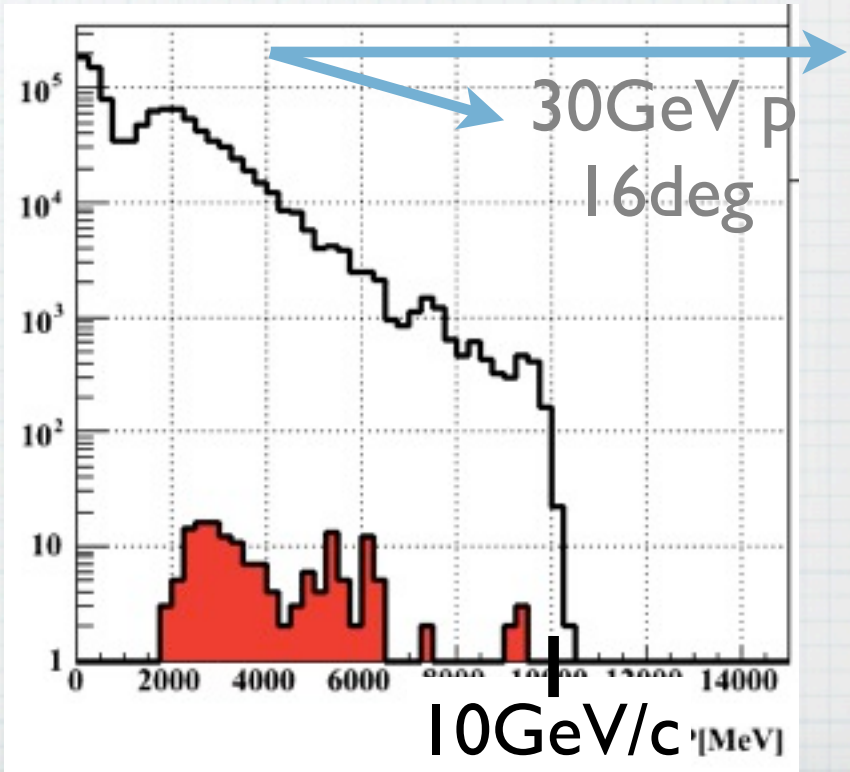
* to suppress π^0 and eta production



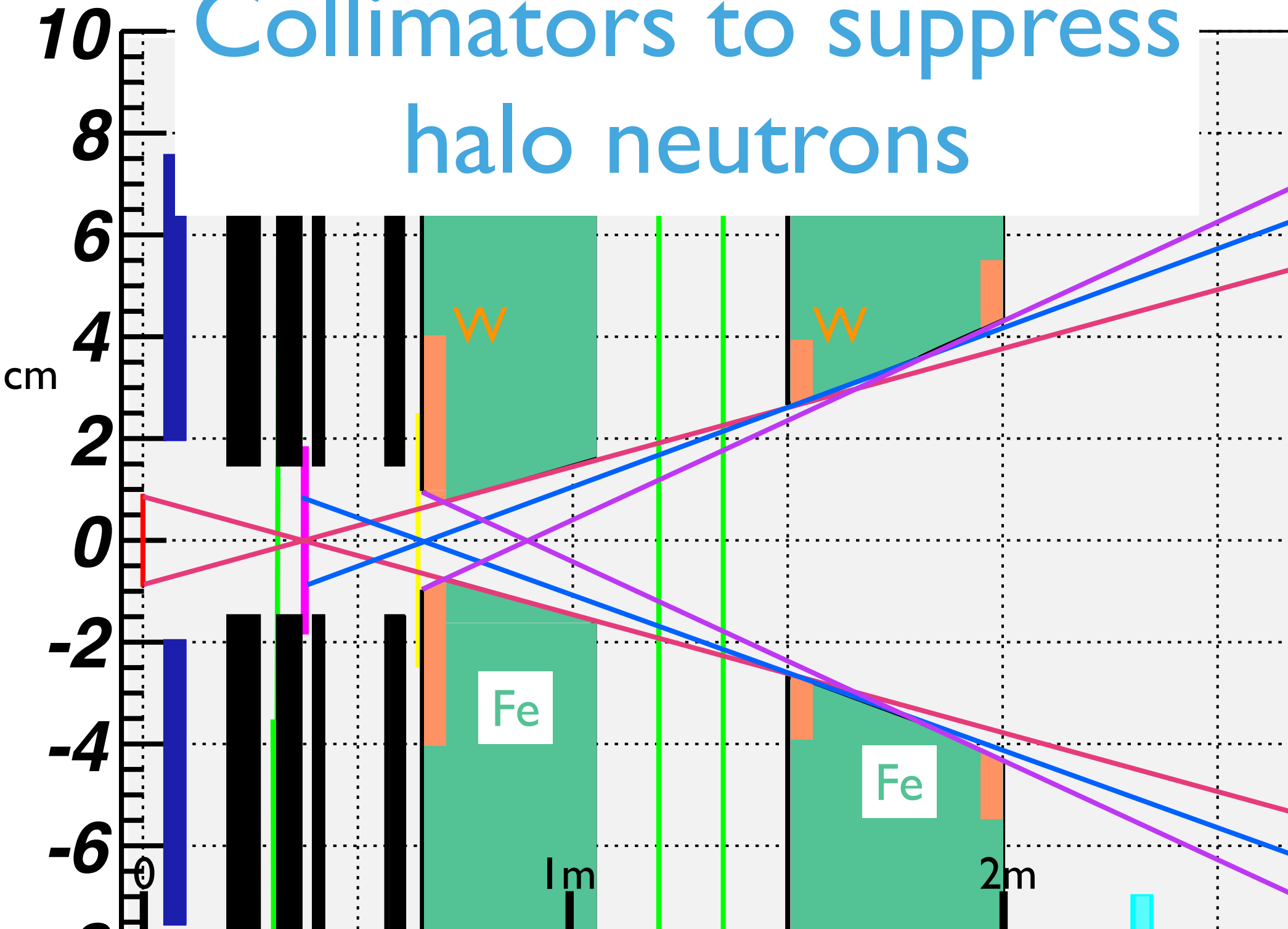
KEK E391a



KOTO

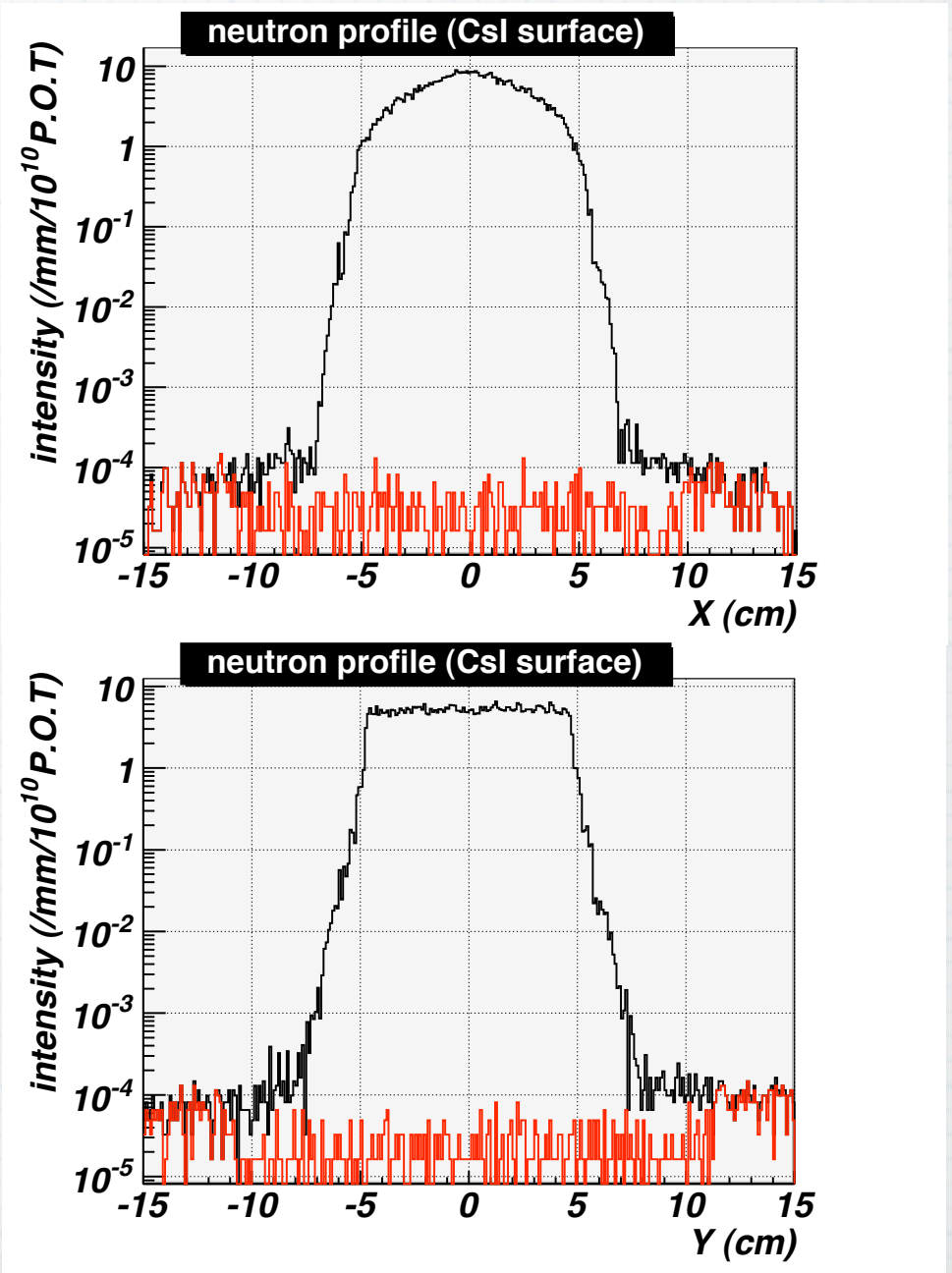


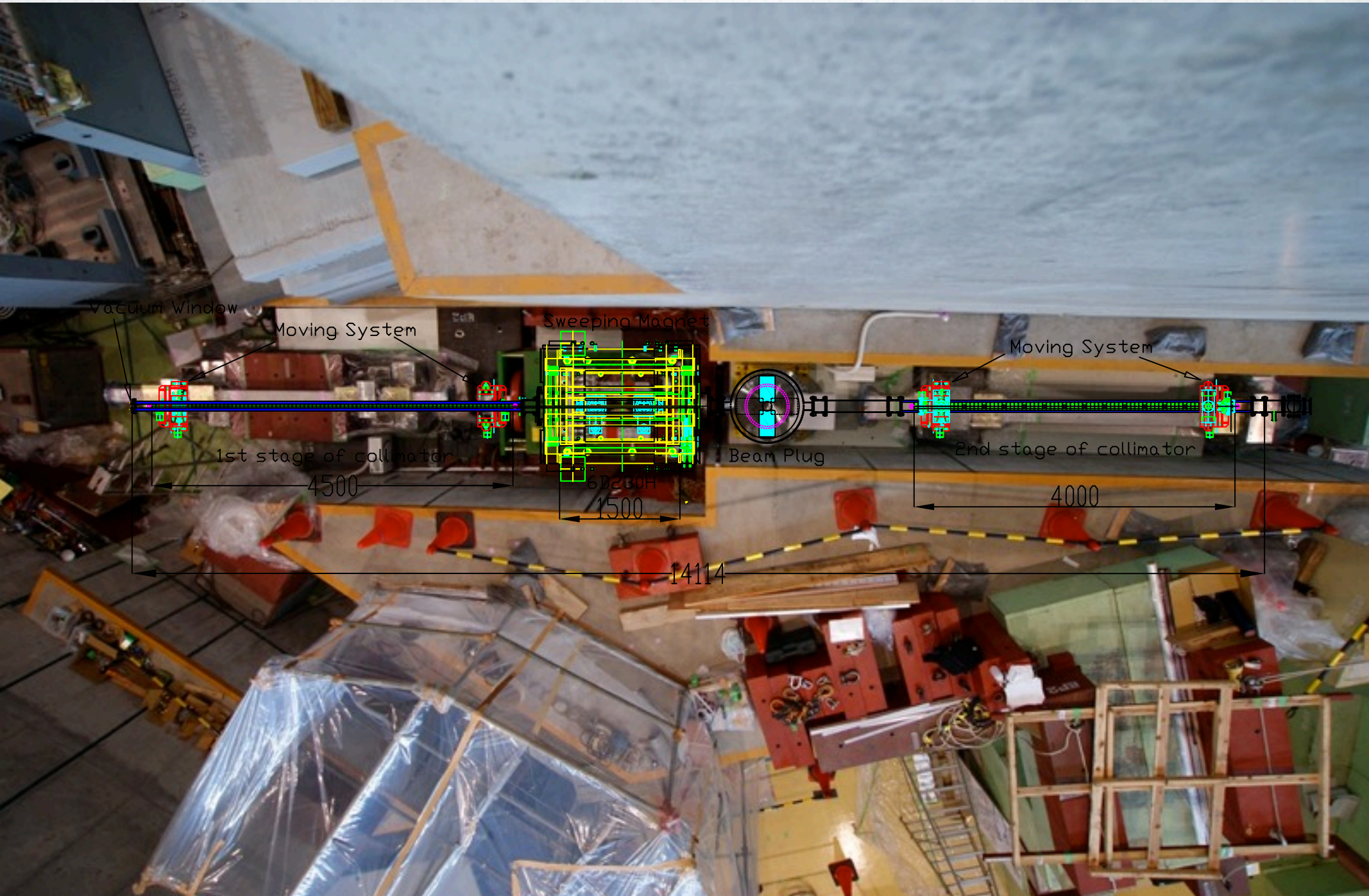
Collimators to suppress halo neutrons

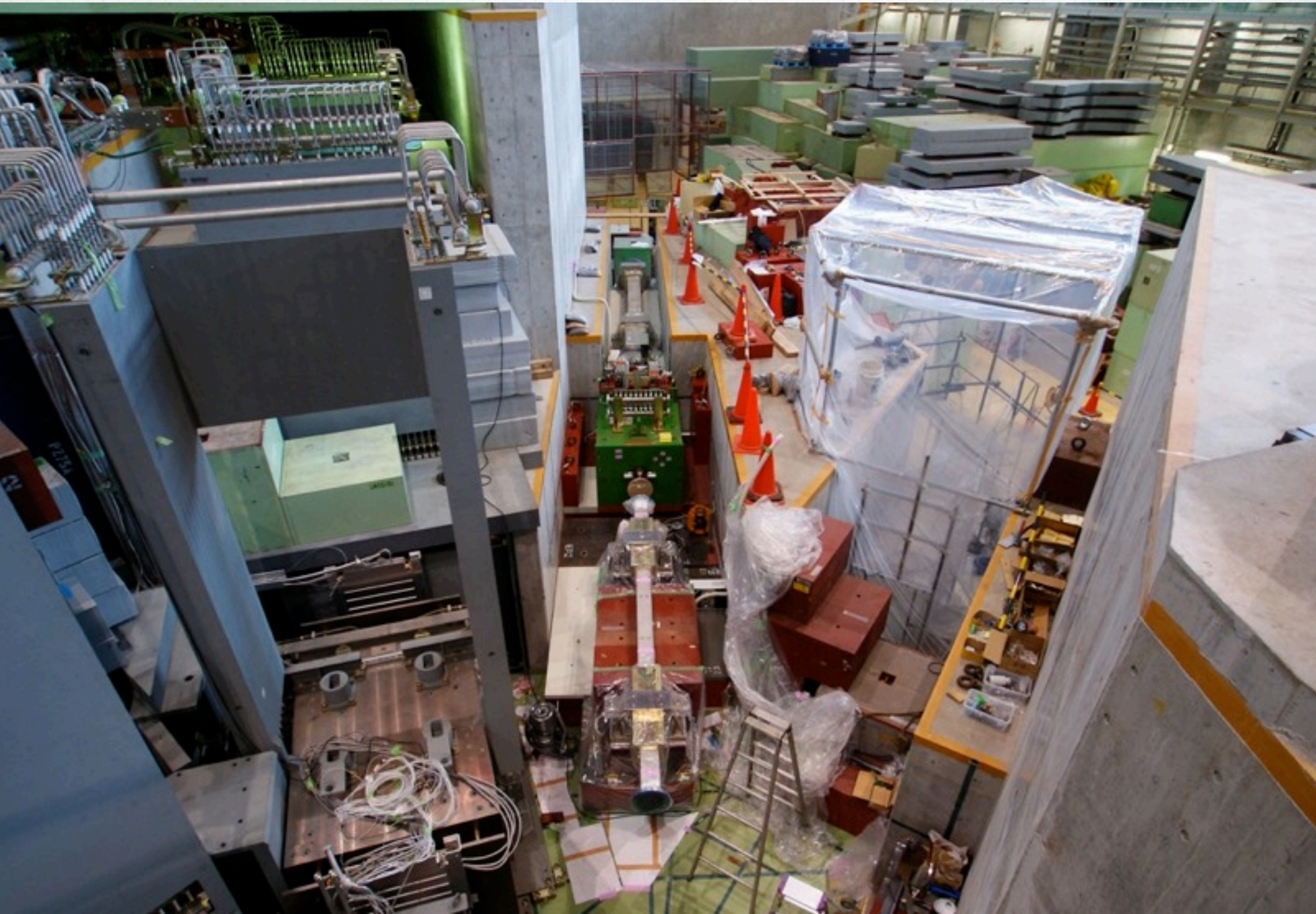


The final beam shape

	#particles/ 2E14 protons on target
halo neutrons (p>0.78GeV/c)	1.0×10^{4}
K_L (T>0.1GeV)	1.5×10^{7}
halo n / K_L	7.0×10^{-4}

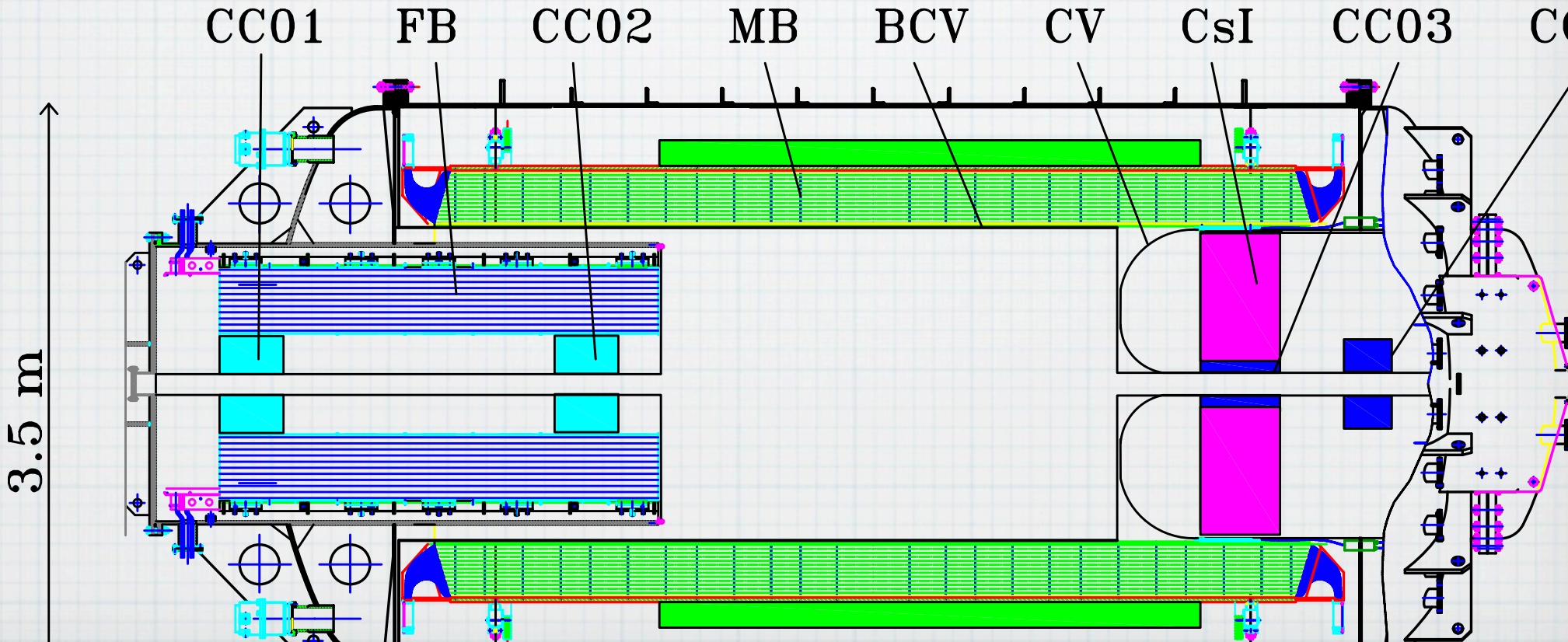



Vacuum Window
Moving System
Sweeping Magnet
Moving System
1st stage of collimator
4500
6D230H
1500
Beam Plug
2nd stage of collimator
4000
14114

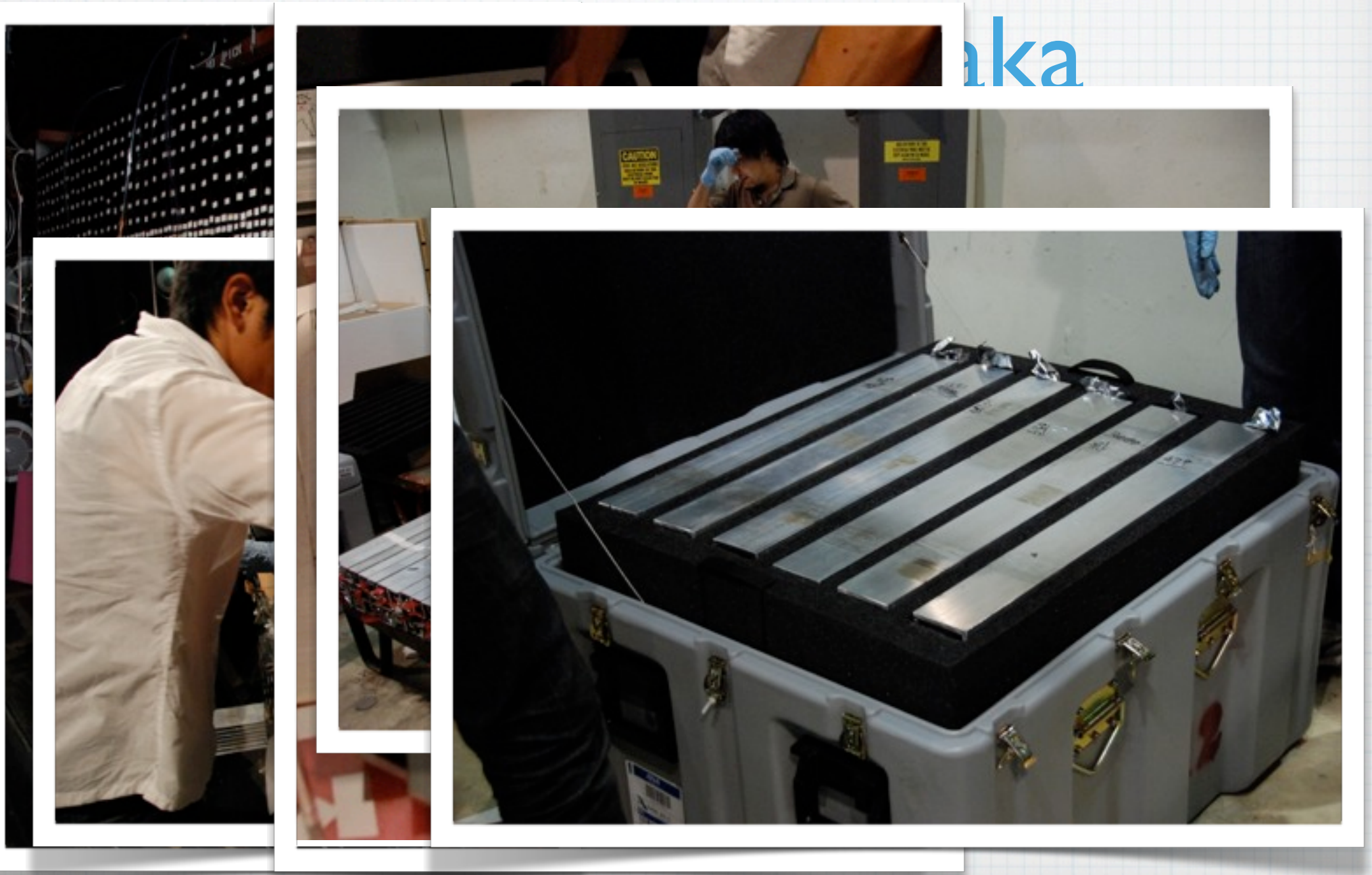


Detector

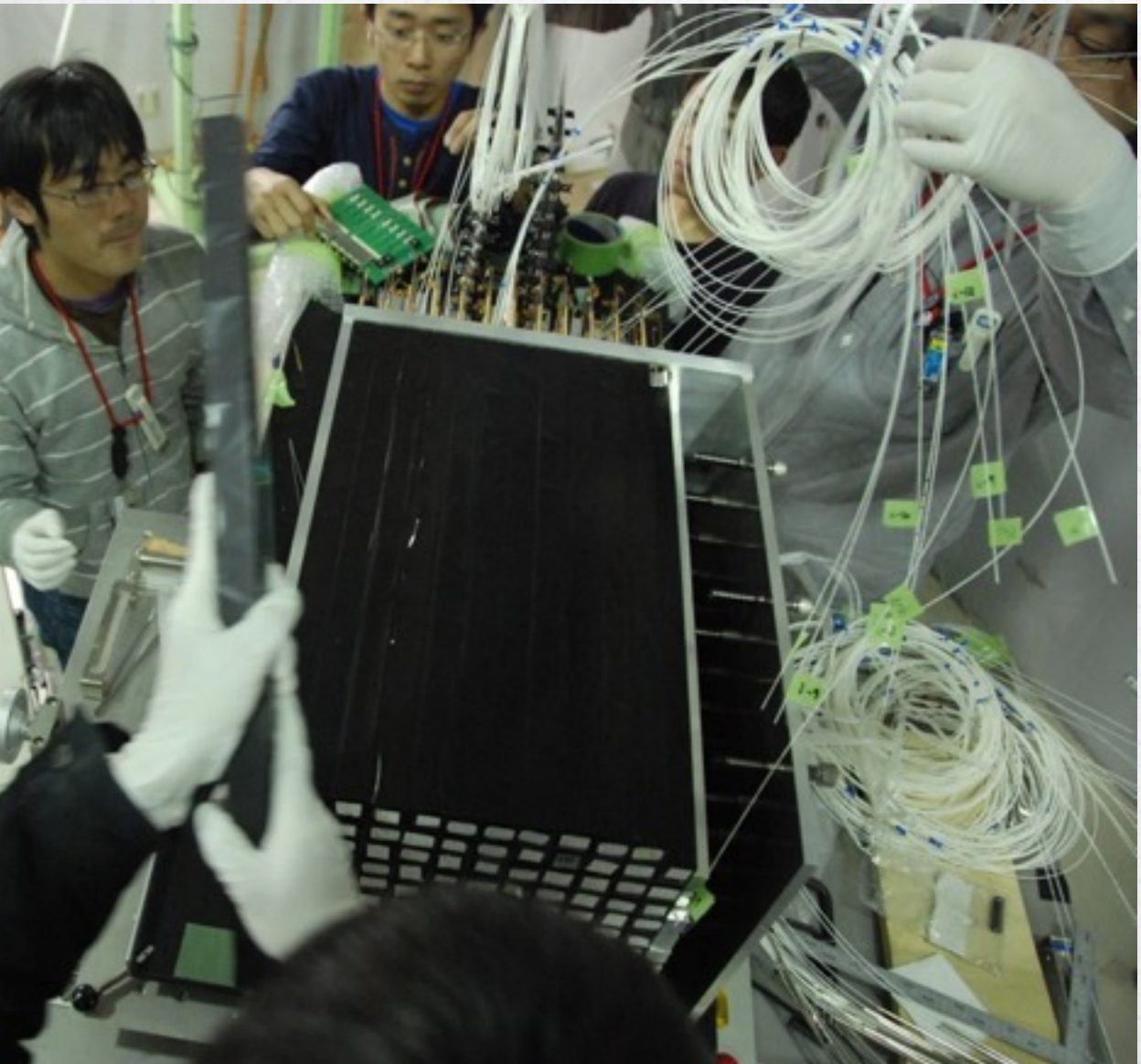
* CsI calorimeter (from KTeV)
* Waveform digitization
* New Charged and Photon Veto detectors

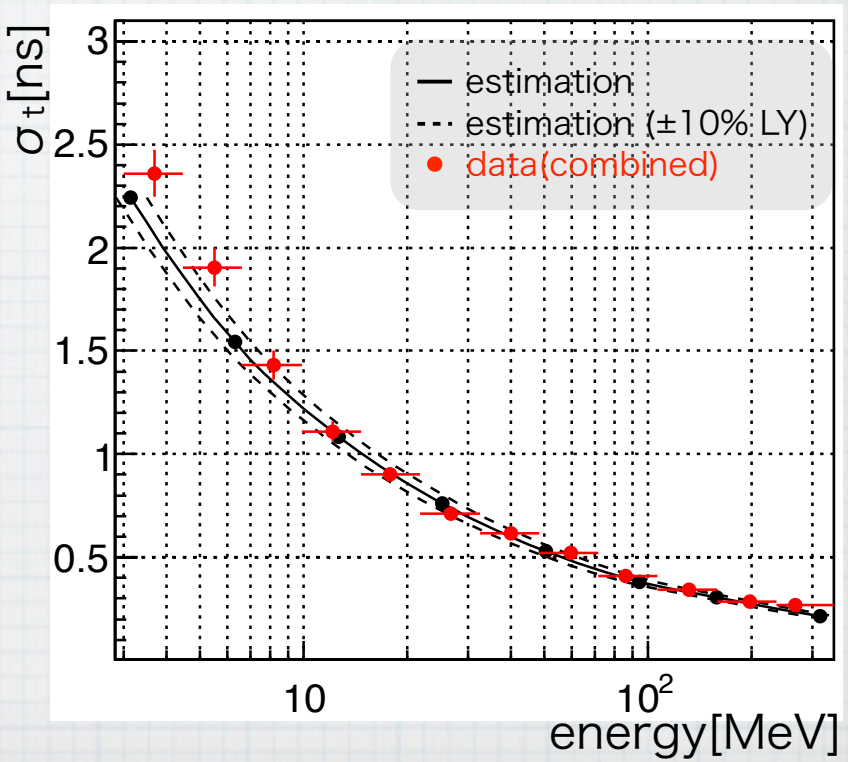


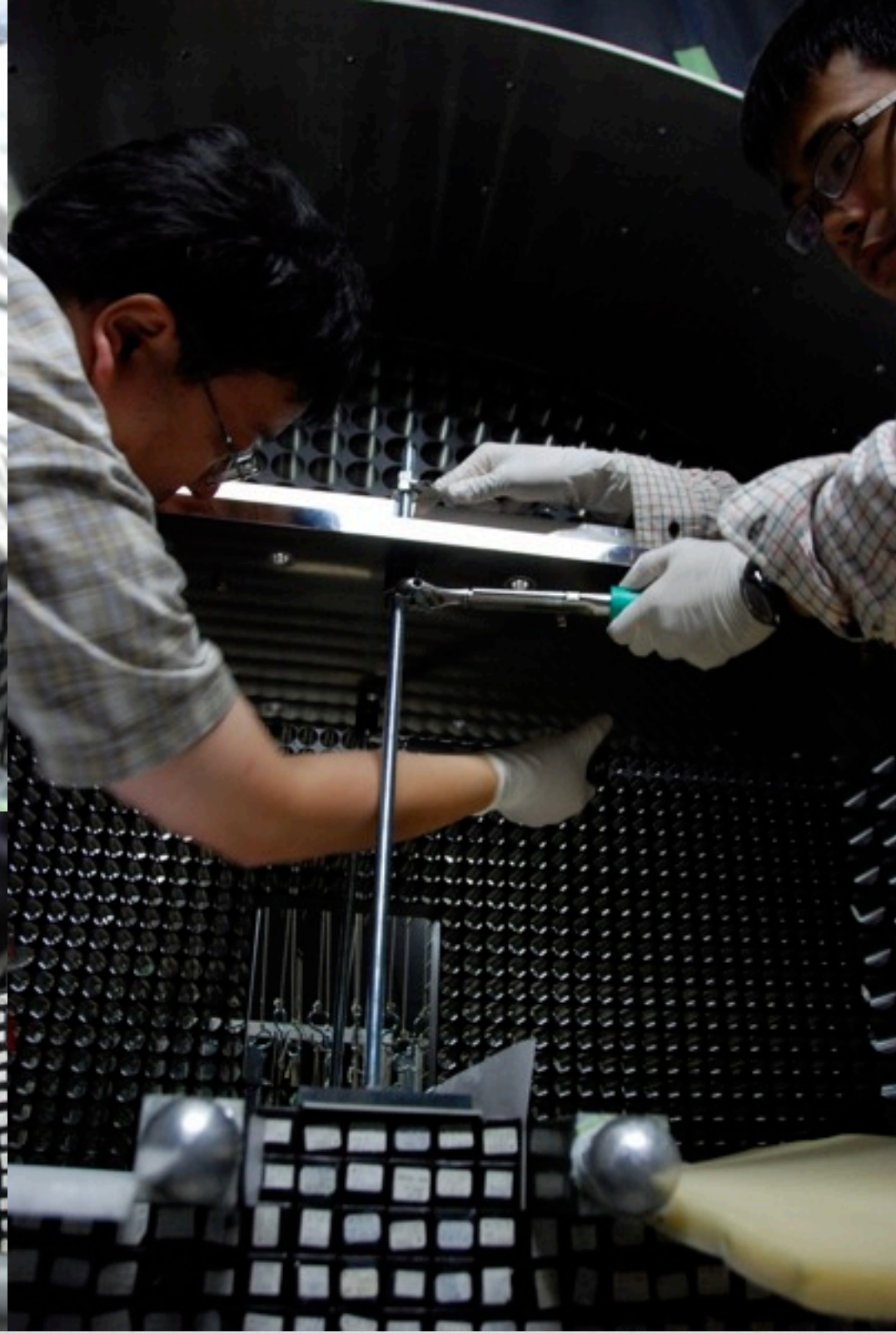
2800 CsI crystals:

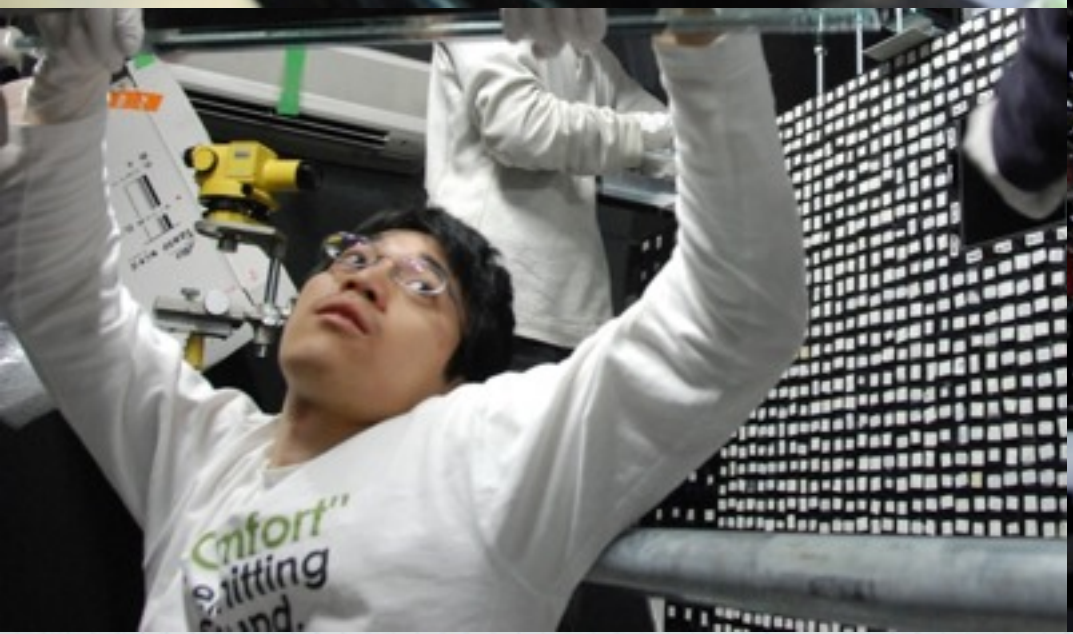


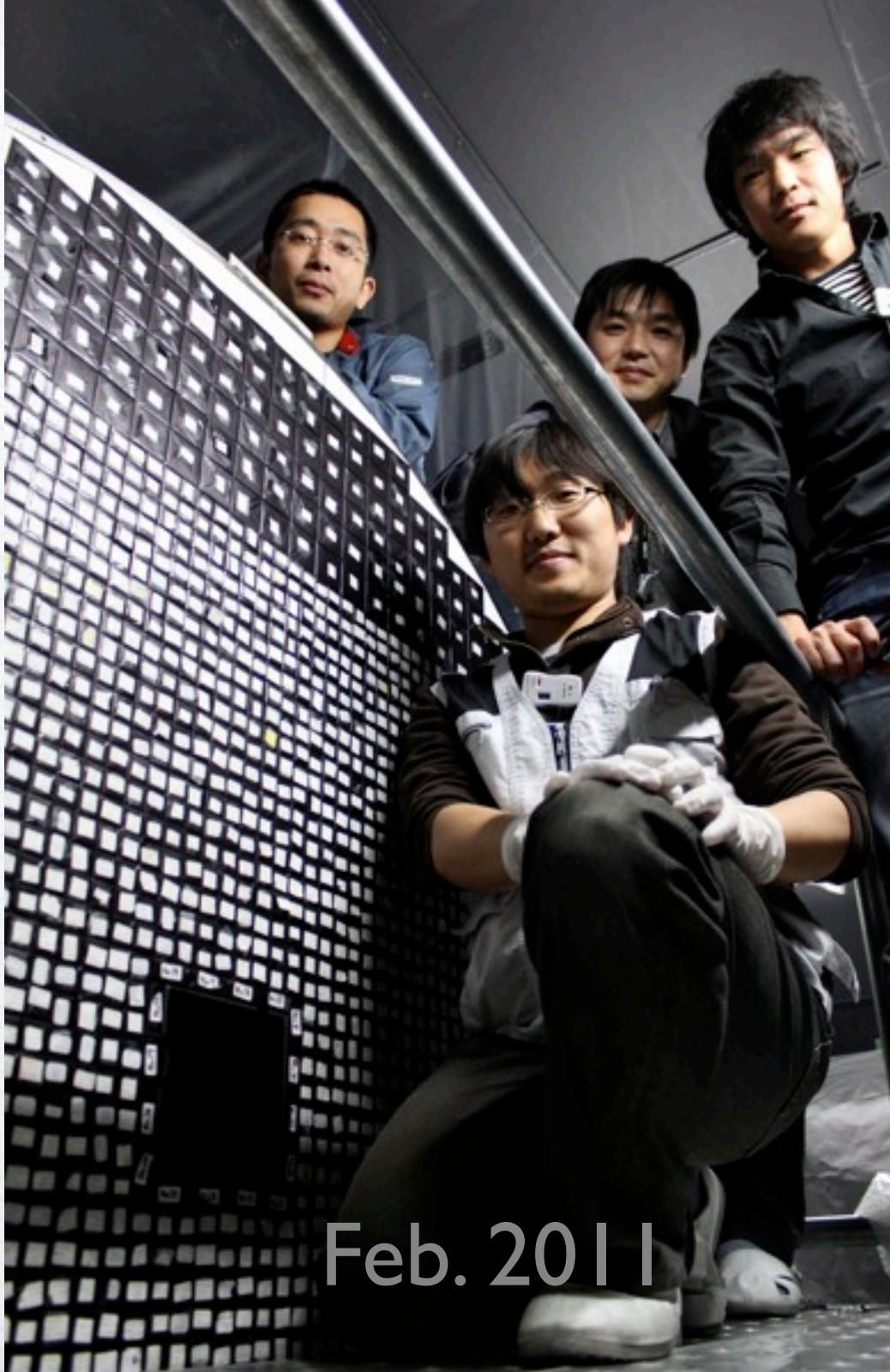
144ch. Test @Sendai





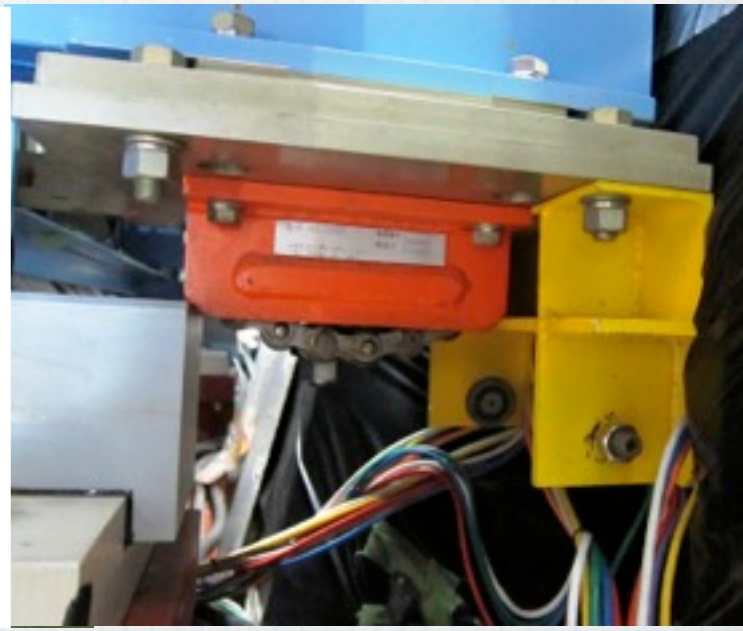





Feb. 2011

29days later, the Earthquake

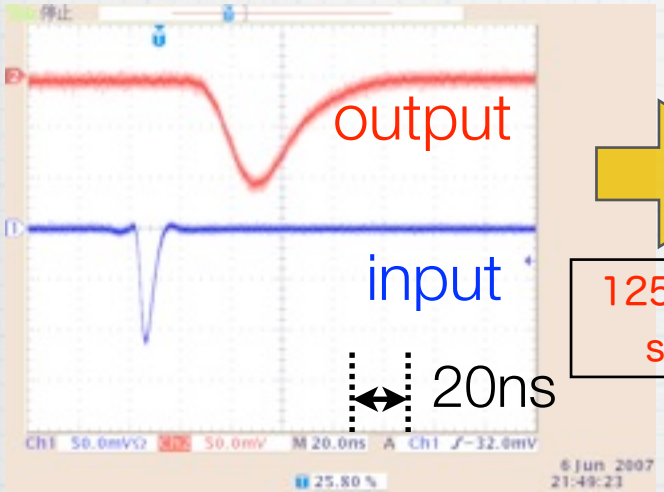
- Nobody was injured
- CsI crystals stayed in place
- CsI endcap almost ran off the rails and stopped by dry room wall



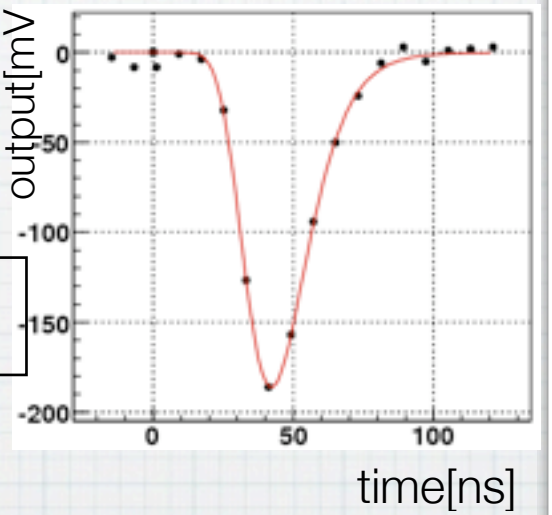
- Electricity was lost for 14 days = no dry air

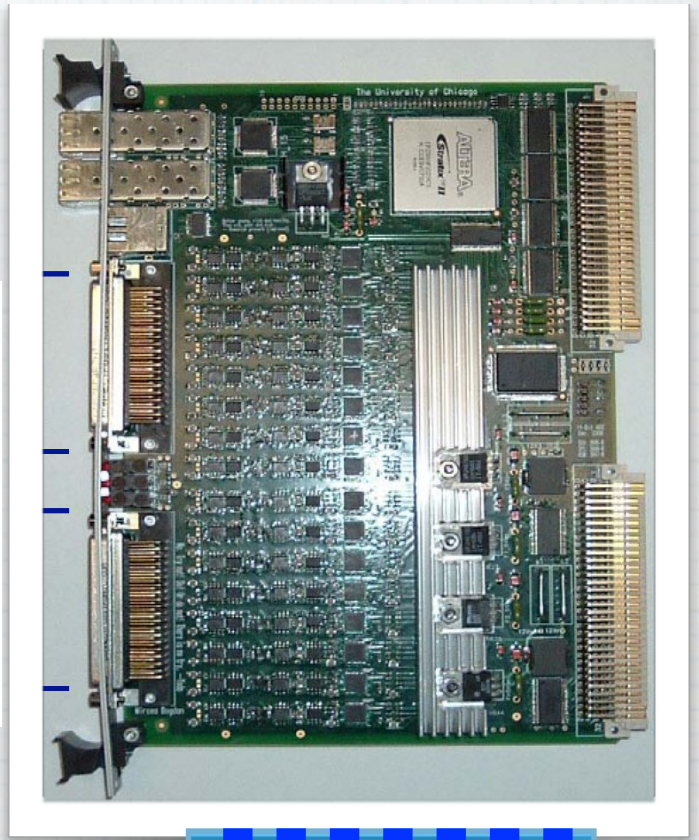
DAQ system

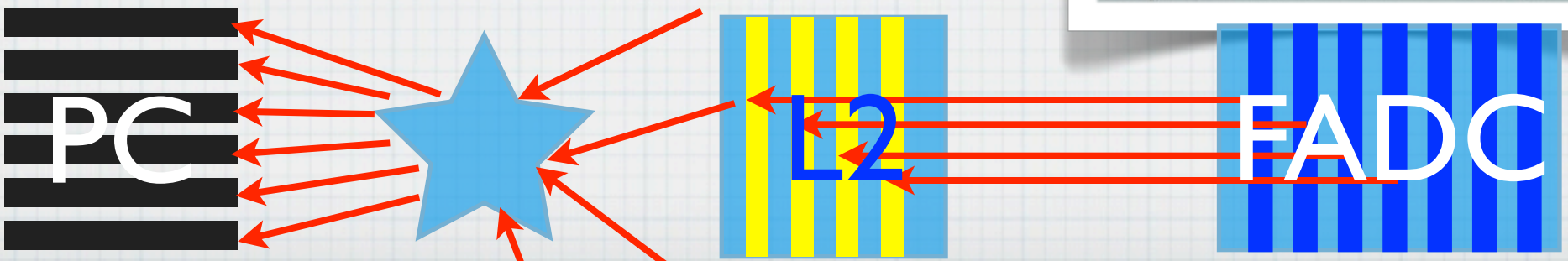
* 14bit FADC to record waveform and
  * to form triggers digitally
* Designed, produced by US



125MHz(8ns) sampling



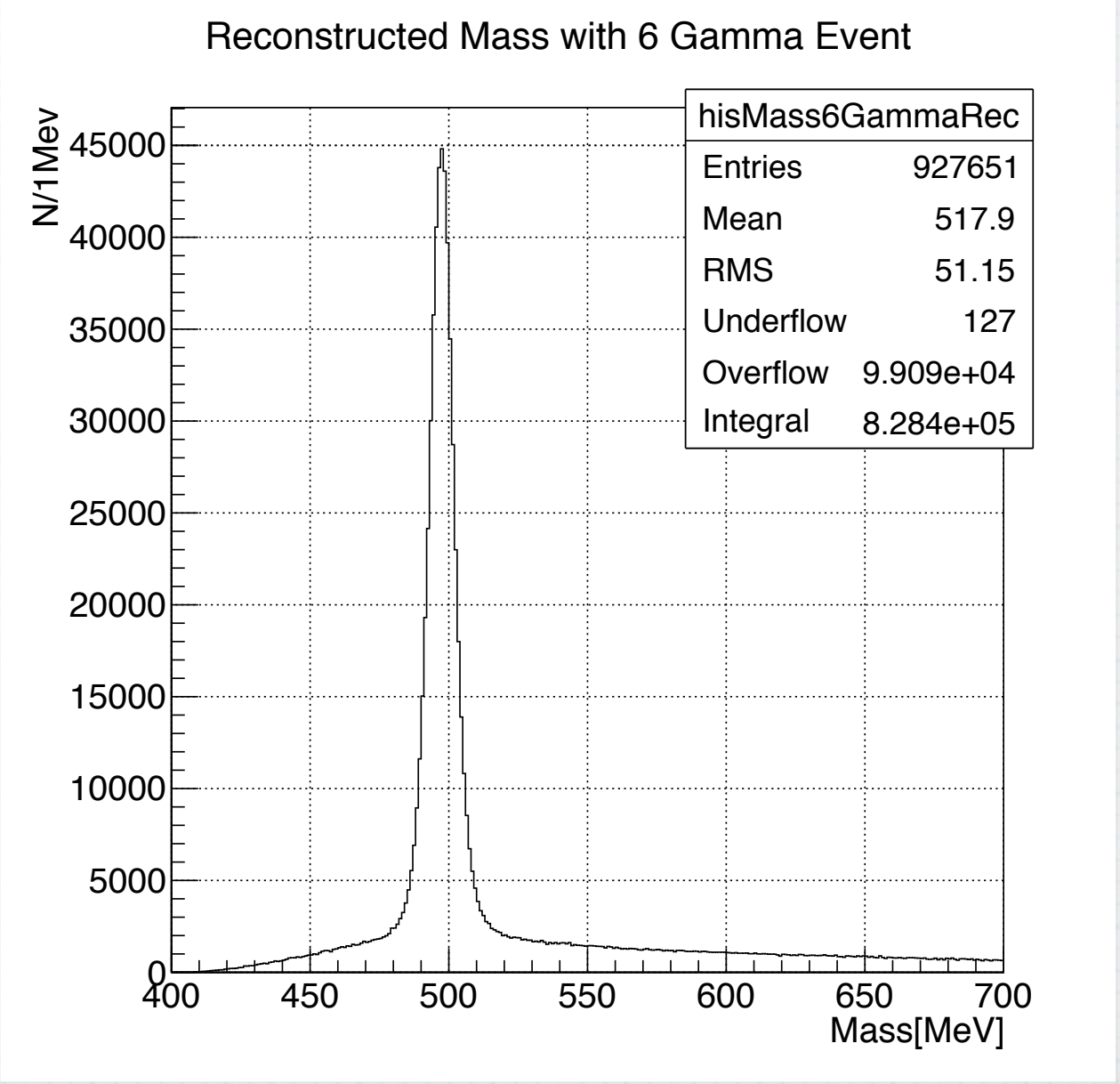




Aug. 2011: Vacuum Test of the CsI Calorimeter

2011 Feb.

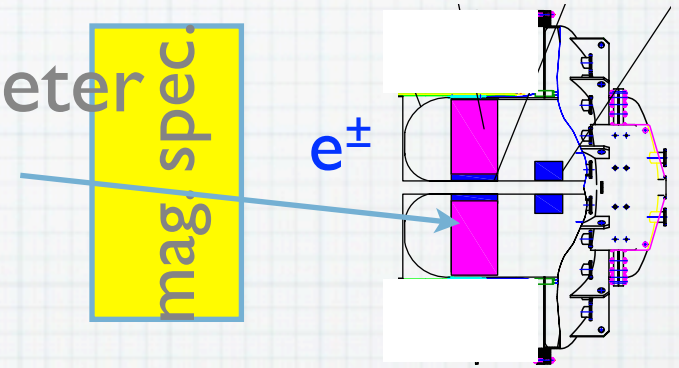
* $K_L \rightarrow 3\pi^0$



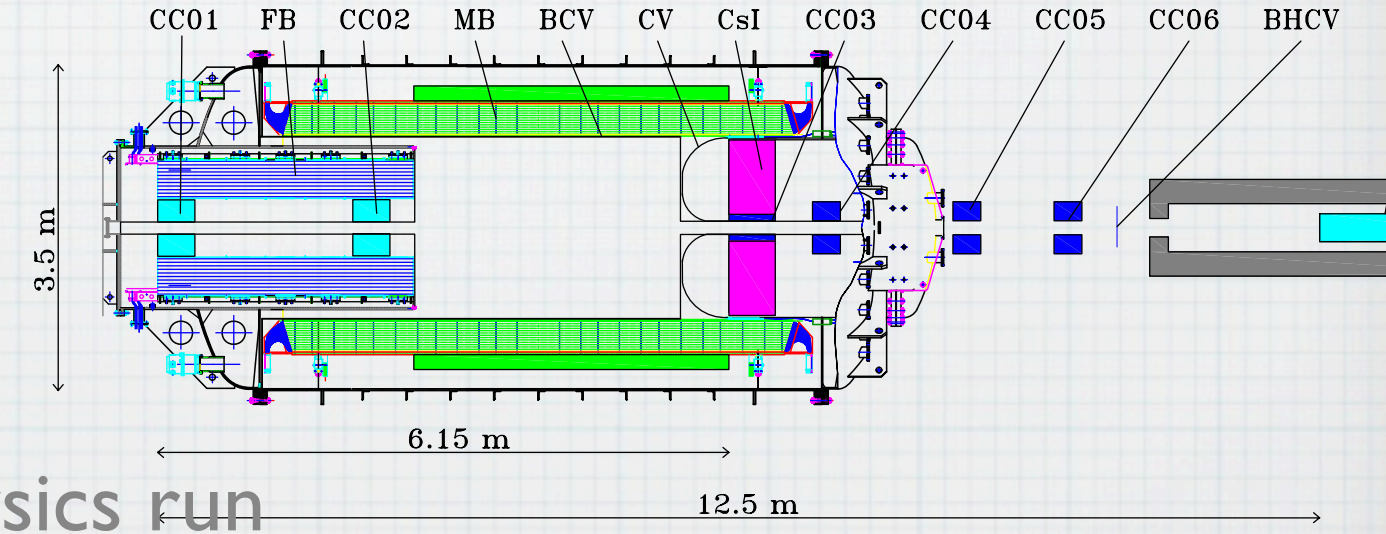
Schedule

* Feb., Jun. 2012: CsI calorimeter

  + magnetic spectrometer

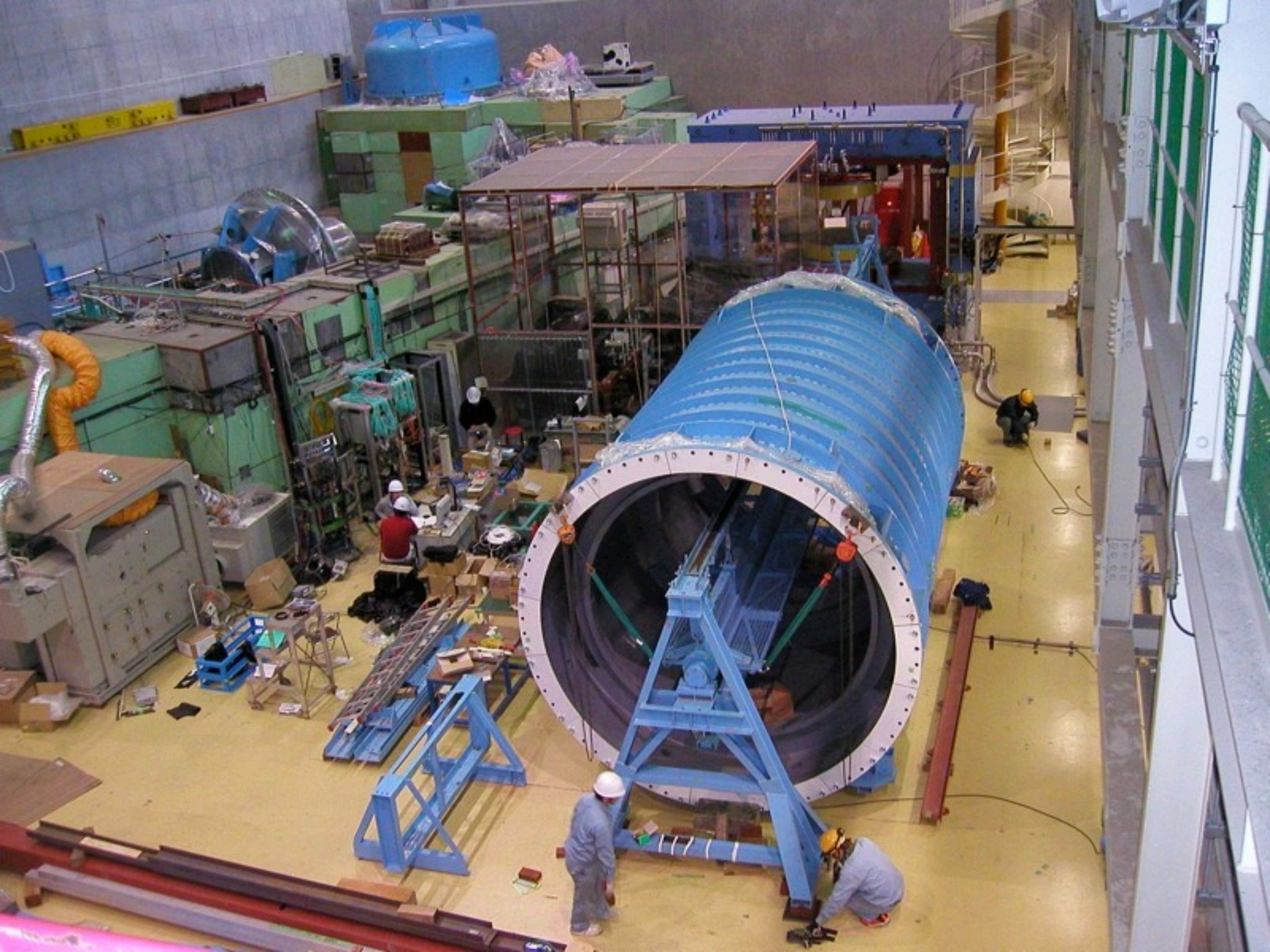


* 2012 Summer: Install other detector components



* 2012 Dec.~

  engineering & physics run

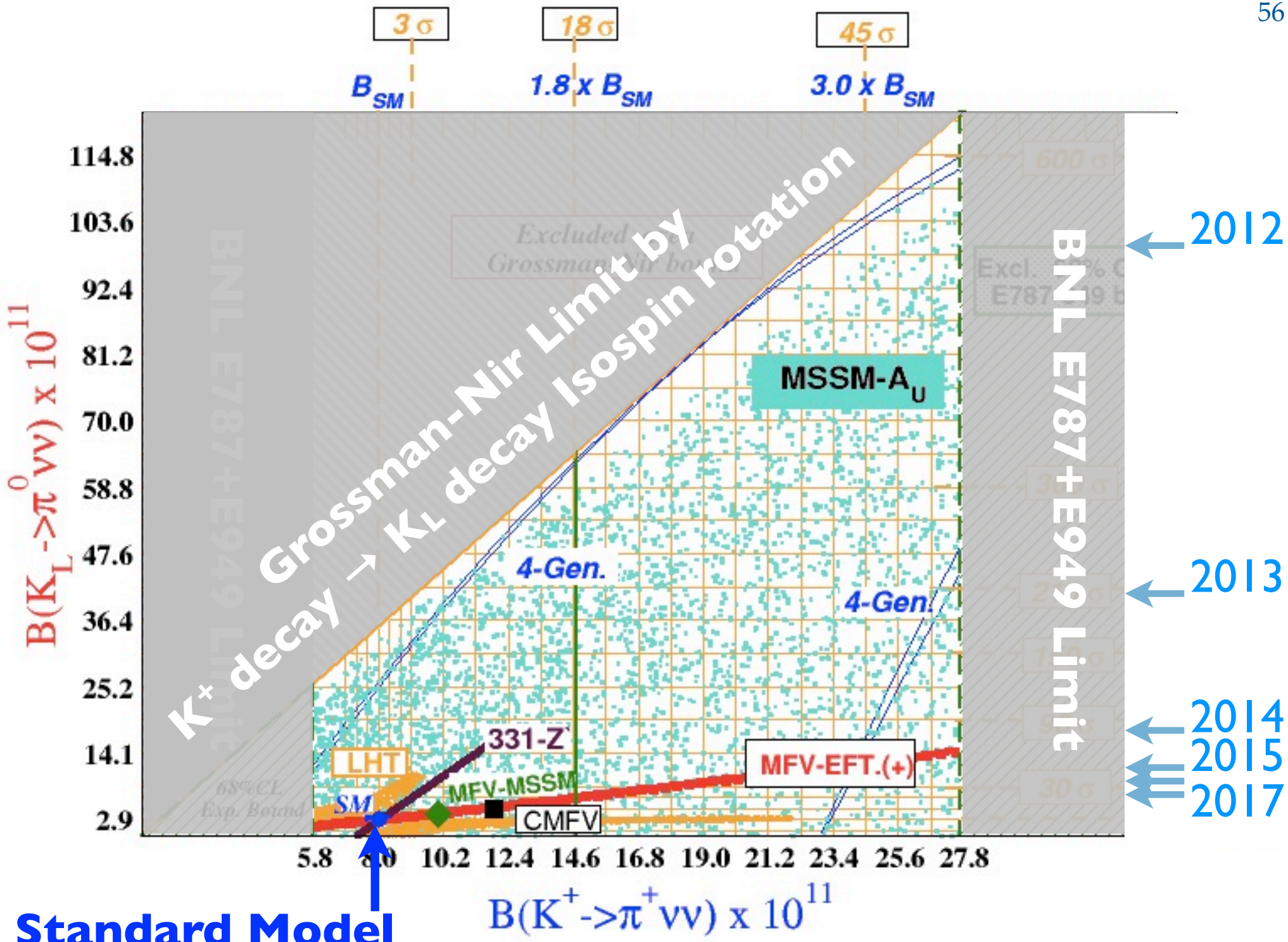


Assumed Beam intensity and time

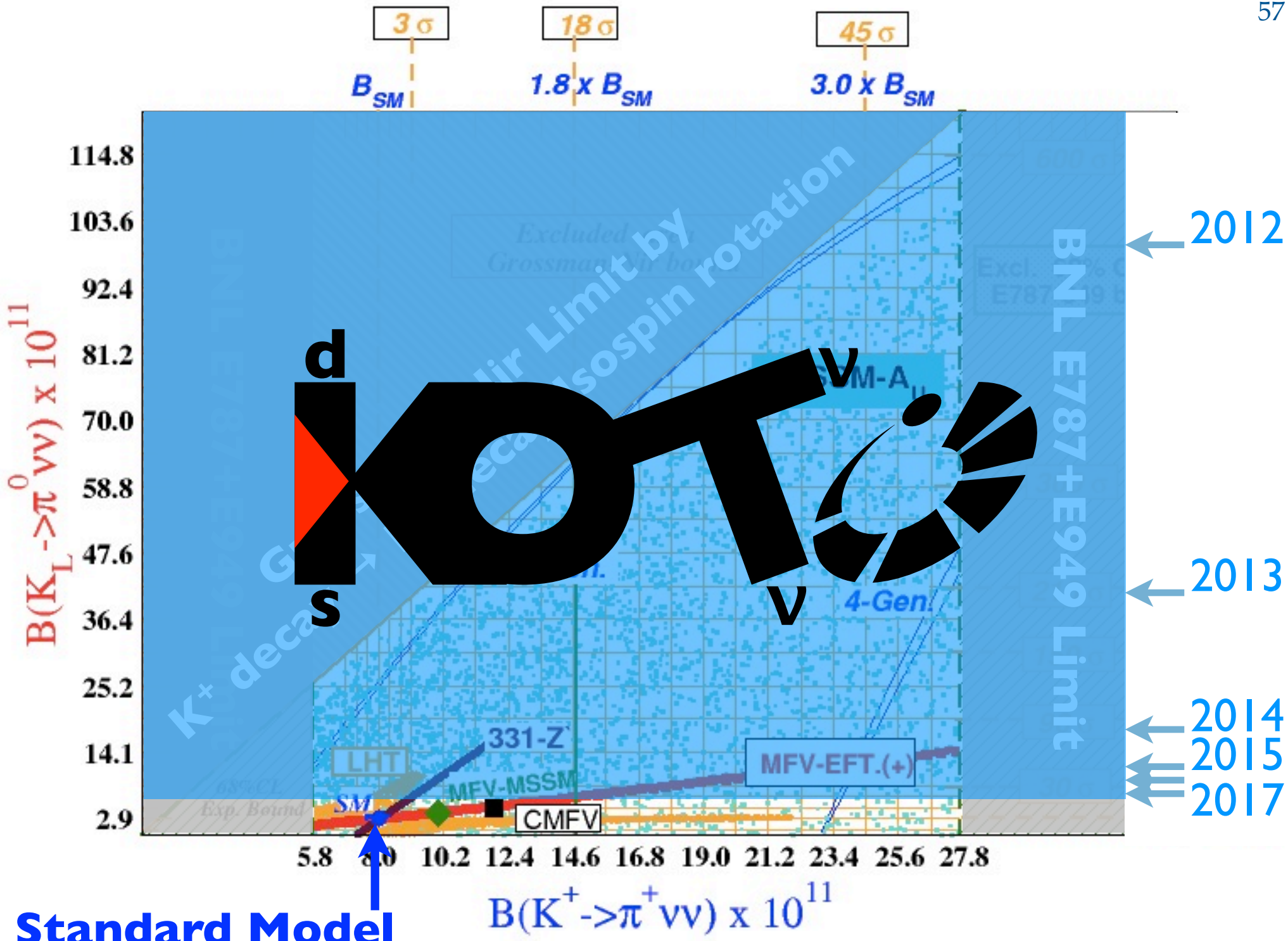
* Koseki@Town Meeting, Aug. 9, 2011

Plan made after the earthquake		
	User operation	Accelerator study
2012.10–2013. 6	10 kW	50 kW
2013. 7–2014. 1 (shutdown)	Li 400MeV/50 mA, Ti chambers (ESS)	
2014. 2–2014. 6	50 kW	100 kW
2014.7 – 9(shutdown)		
2014. 10–	100 kW	

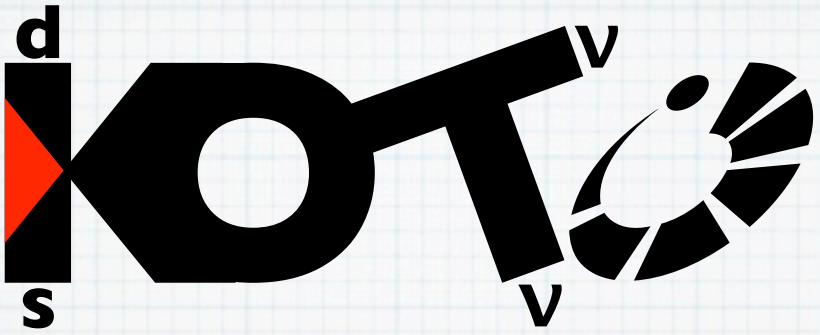
* Assume 1/2 of the beam time for slow extraction
  * 2012: 10kW x 4 months
  * 2014 spring: 50kW x 2 months
  * 2014 fall: 100kW x 4 months
  * 2015: 100kW x 4 months
  * ...



http://www.lnf.infn.it/wg/vus/content/Krare.html



http://www.lnf.infn.it/wg/vus/content/Krare.html



* Thanks to "Flavor Tokutei", the "crazy idea" is finally turning into a reality.
* Still many work to be done. New comers are welcome!

Discovery Level