

Status of the E391a experiment その1



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Outline

- Introduction
 - Physics Motivation
- KEK-E391a
 - Method
 - Apparatus ■
 - Schedule
 - Preparation
 - Detector Construction
- Summary

$$K_L^0 \rightarrow \pi^0 \pi^-$$



Theoretical Background

$K_L^0 \rightarrow \pi^0 \nu \bar{\nu}$ ~ Theoretical Background ~

$$Br(K_L^0 \rightarrow \pi^0 \nu \bar{\nu}) \approx 1.8 \times 10^{-10} \cdot \eta^2 \approx 3 \times 10^{-11}$$

➤ Flavor Changing Neutral Current

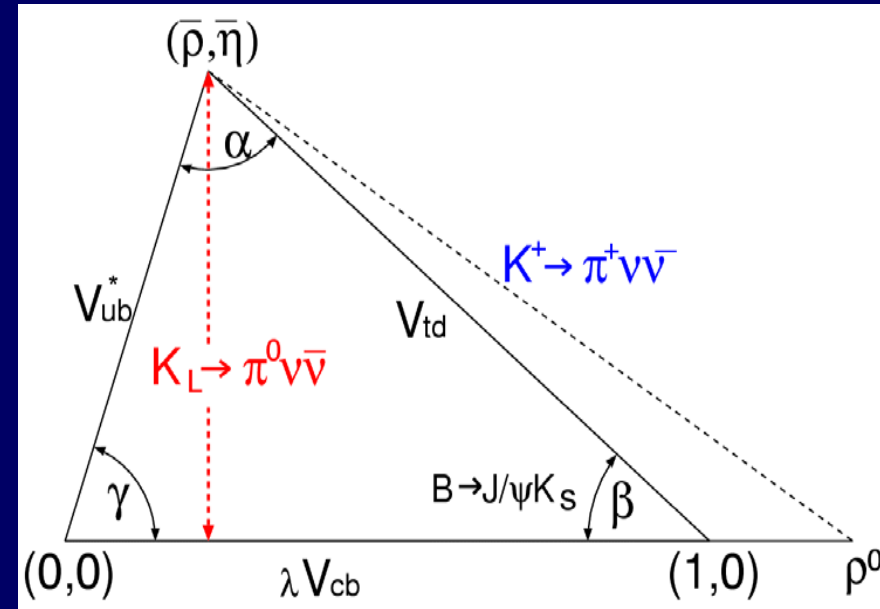
➤ Direct CP violating process ($\epsilon = 1$)

➤ **Theoretical uncertainty** : Very Small! (\sim few % error)

➤ The hadron matrix element can be factorized
as the well-know $K \rightarrow \pi e \bar{e}$ decay!

➤ One of best tool to determine
CP-violation parameter,

➤ Clue for the new physics

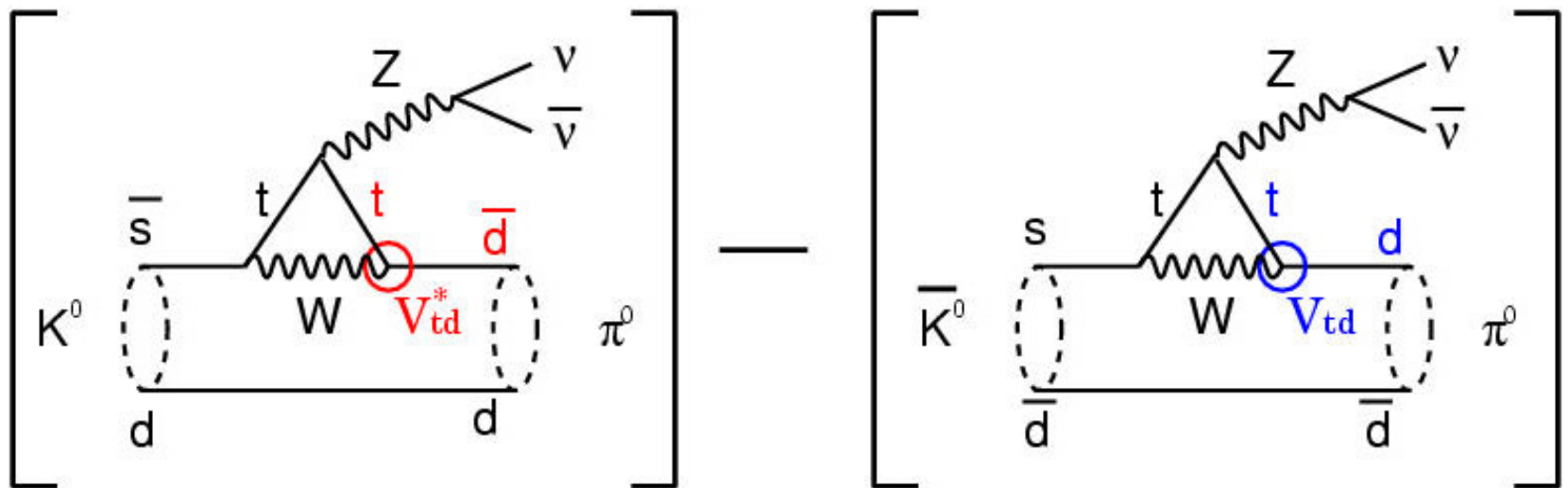


$$K_L^0 \rightarrow \pi^0 \nu \bar{\nu}$$

$$K_L^0 \equiv \varepsilon_K K_1 + K_2 \approx K_2 = K^0 - \bar{K}^0$$

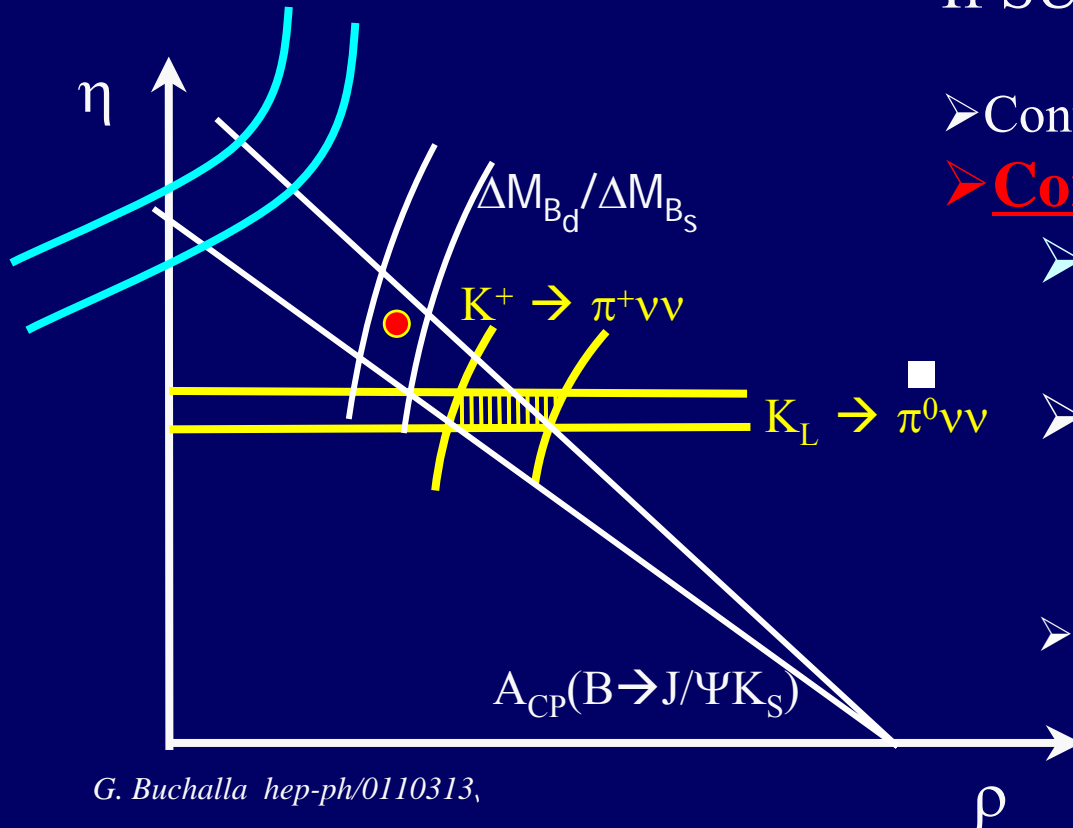
$$\Rightarrow A(K_L^0 \rightarrow \pi^0 \nu \bar{\nu}) \approx A(K^0 \rightarrow \pi^0 \nu \bar{\nu}) - A(\bar{K}^0 \rightarrow \pi^0 \nu \bar{\nu})$$

$$\propto V_{td}^* - V_{td} \propto \text{Im}(V_{td}) = \eta$$



BSM effect

★ Unitarity Triangle vertices



G. Buchalla hep-ph/0110313,

For example:

If SUSY (MSSM) effect exists...

hep-ph/9908499

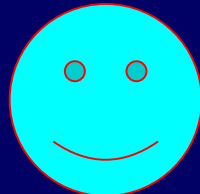
➤ Contribution $< \sim 10\%$

➤ Correlation

➤ \rightarrow enhanced

➤ $Br(K \rightarrow \dots)$
 \rightarrow suppressed

➤ $M_{B_s}, A(B \rightarrow J/\Psi K_S)$
 \rightarrow unchanged



These correlations strongly depend on the Model!

Combination of K decays and B decays might give **clue for new physics**

$$K_L^0 \rightarrow \begin{matrix} 0 \\ \hline \end{matrix}$$



Experimentally Challenges

$$\text{Br}(K_L \rightarrow \pi^0 \pi^0) \sim 3 \times 10^{-10} \rightarrow$$

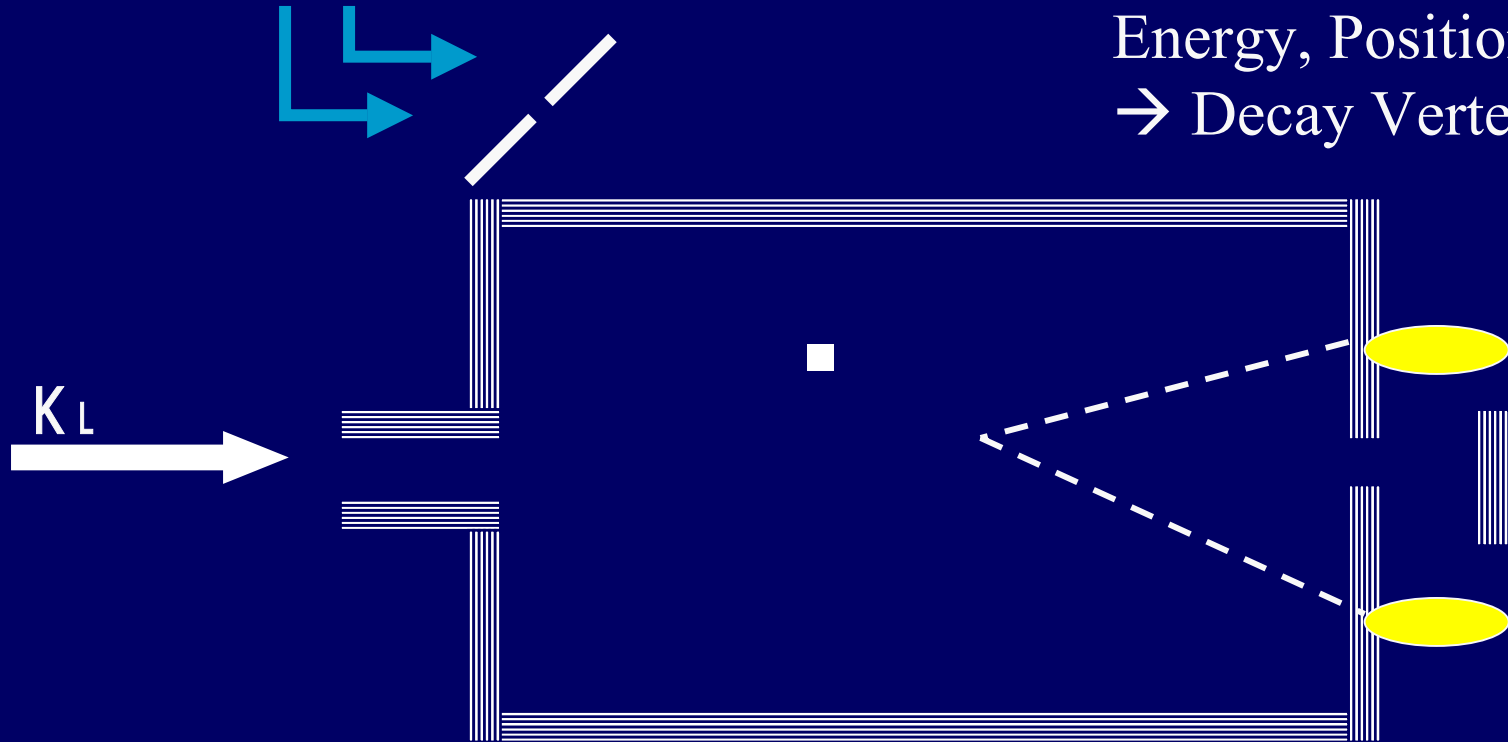
+ nothing

$$\text{Br}(K_L \rightarrow \pi^+ \pi^-) = 5.86 \times 10^{-5} \rightarrow$$

($P_T=0$)

$$\text{Br}(K_L \rightarrow \pi^0 \pi^0) = 9.27 \times 10^{-4}$$

Pencil Beam(K_L) \rightarrow
Energy, Position of ?
 \rightarrow Decay Vertex, P_T



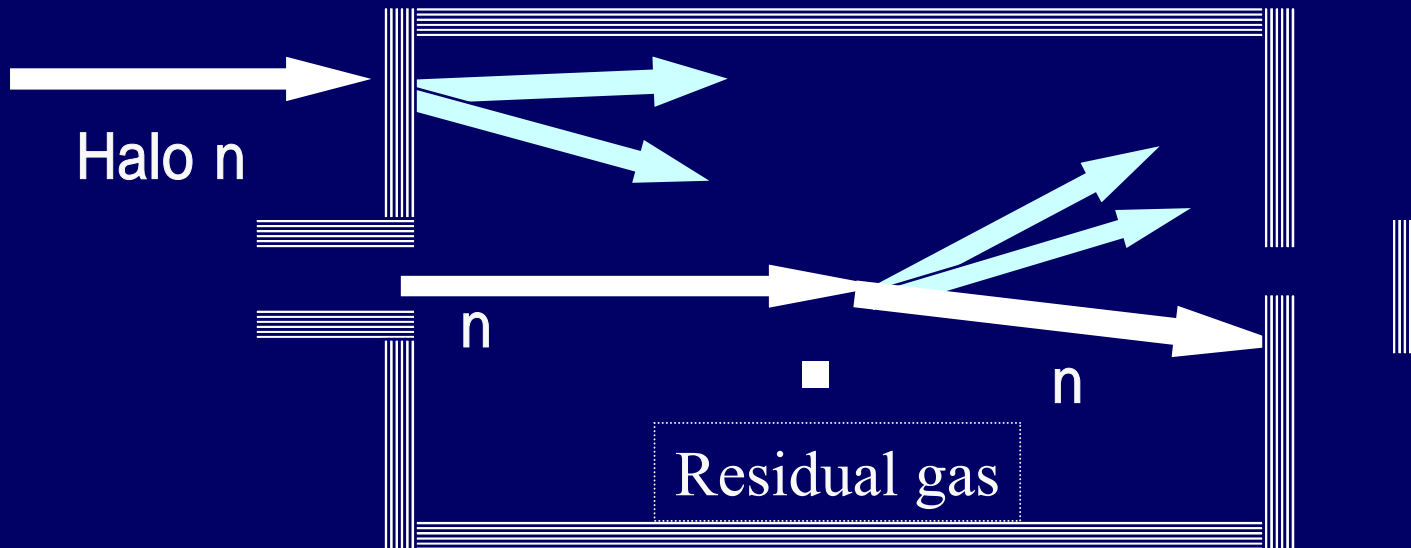
The largest background rejection power :

Veto on extra

Detection efficiency $\sim 99.99\%$

One more things...Beam-related backgrounds

✧ Single π^0 is copiously produced by $n+n \rightarrow n+n+\pi^0$



➤ Clean beam (beam halo)

✧ Low vacuum pressure 10^{-5} Pa.

Important Issues

- Detector
 - Highly Hermetic → 4 coverage with thick calorimeter.
 - Better veto → ~ 1 MeV threshold
- Beam line ■
 - Tightly-collimated K_L beam
 - Clean beam ... low neutron halo! → 5 stage collimation
- Low vacuum pressure operation
 - whole detector in vacuum
- Based on these points...

KEK-E391a Experiment



~ First Dedicated Search ~

Collaboration

*High Energy Accelerator Research Organization, **KEK***

*Faculty of Science and Engineering, **Saga University***

*Department of Physics, **Yamagata University***

*Department of Physics, **Osaka University***

Research Center for Nuclear Physics, Osaka University

National Defense Academy of Japan

*Joint Institute for Nuclear Research (Dubna) **Russia***

*Department of Physics, **University of Chicago***

Fermi National Accelerator Laboratory

*Department of Physics, **Pusan National University***

10 Institutes from 4 countries, over 50 collaborators.

KEK-E391a experiment

Target: Single Event Sensitivity

$$\text{Br}(K_L \rightarrow \quad^0 \quad) \sim 3 \times 10^{-10}$$

current upper limit : 5.7×10^{-7} by FNAL-KTeV

Standard Model prediction : $\text{Br} \sim 3 \times 10^{-11}$

Pilot experiment for J-PARC era

- Verify our method
- Unexpected source of background
- Signatures of backgrounds

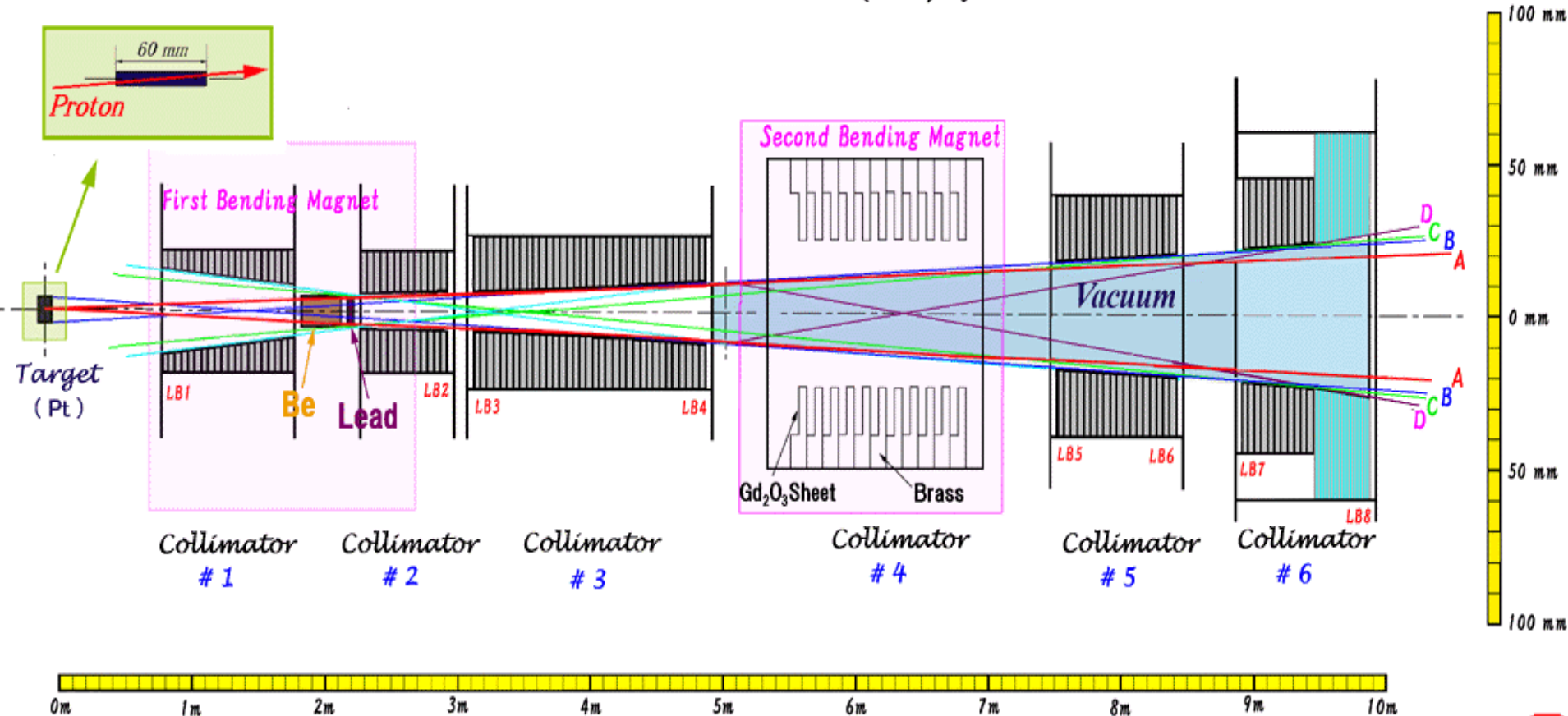
✧ Experiment has been started from Feb. 2004 !

New K0 beam line for E391a

KO BEAM LINE LAYOUT IN EAST HALL AT KEK

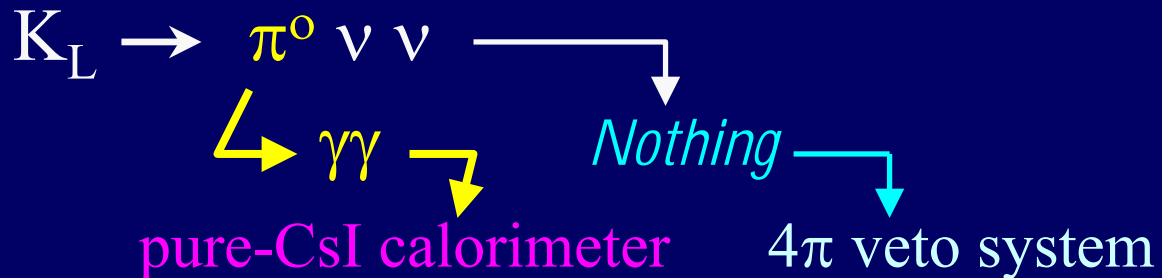
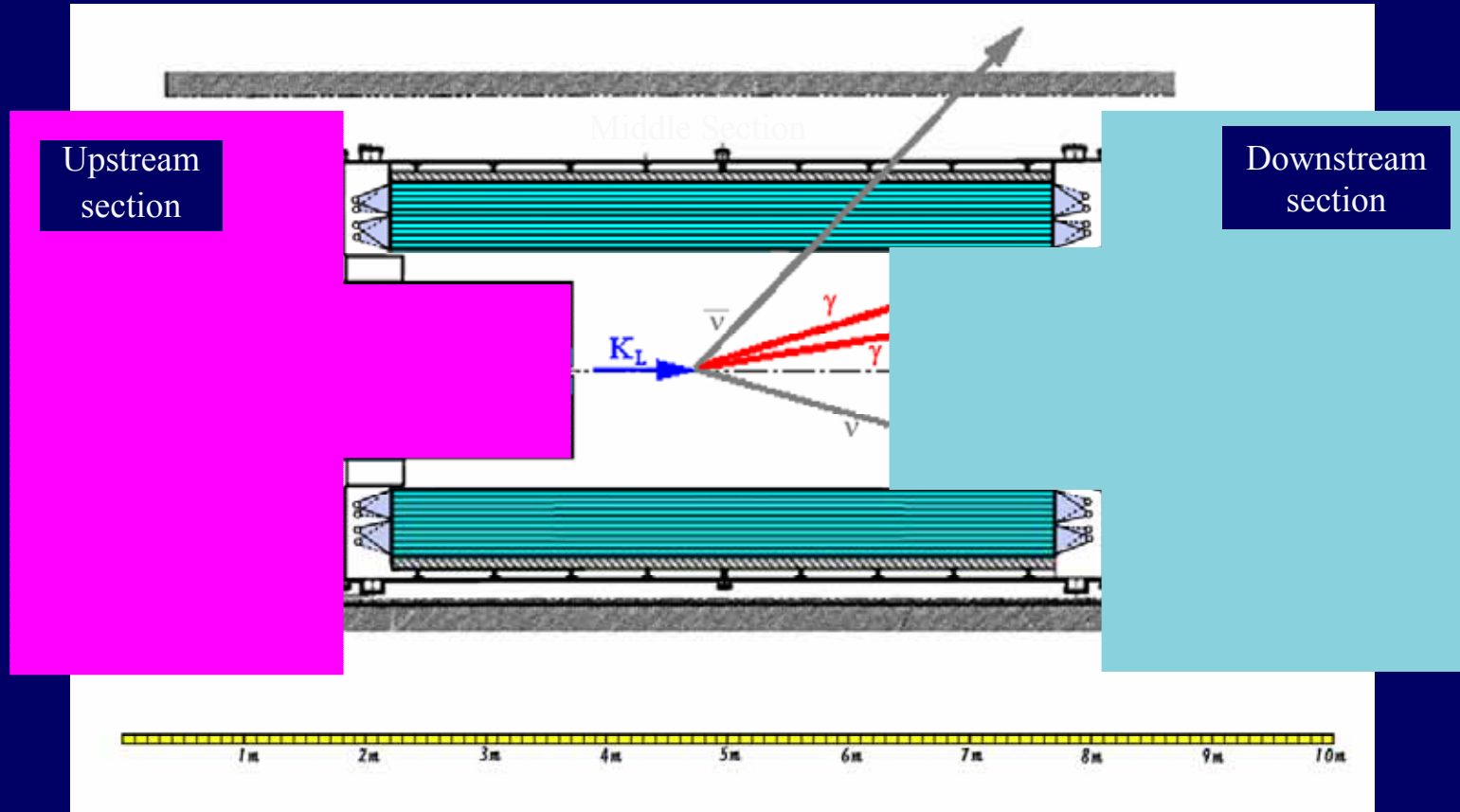


Neutral Beam Line (K0) for E391a



The Construction was finished on March, 2000

E391a Detector Layout



Upstream

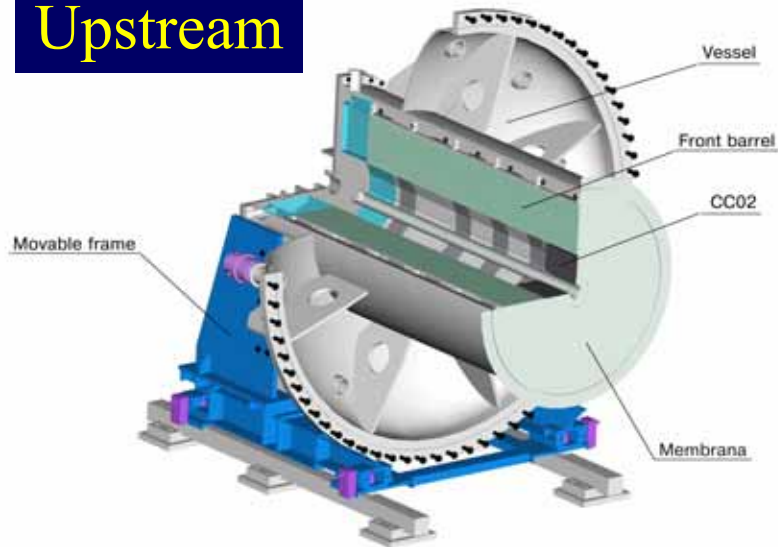


Fig.2

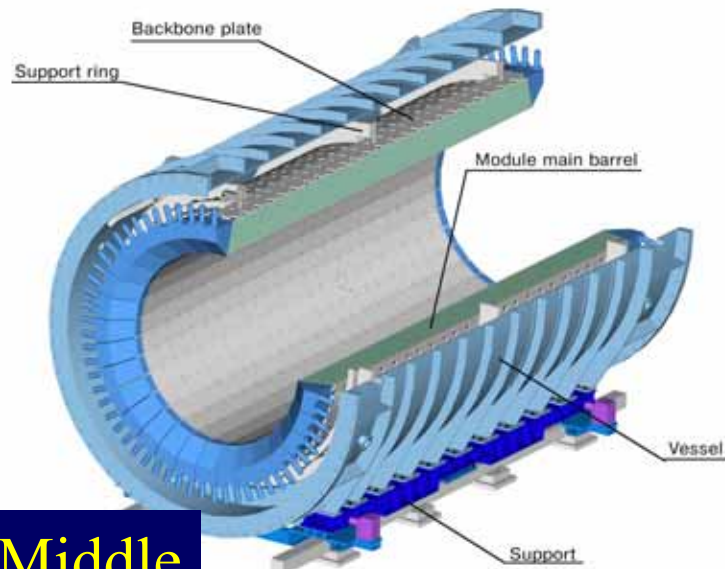


Fig.3

Middle

Downstream

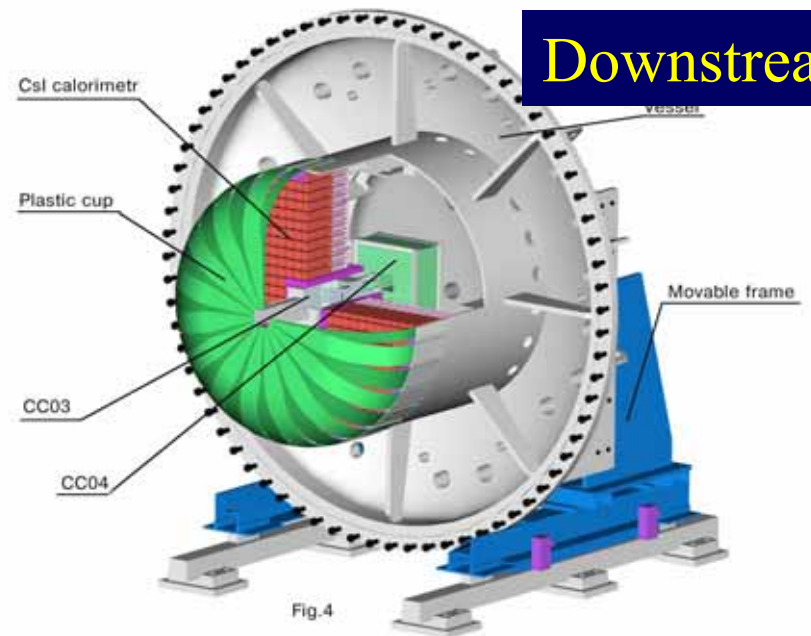
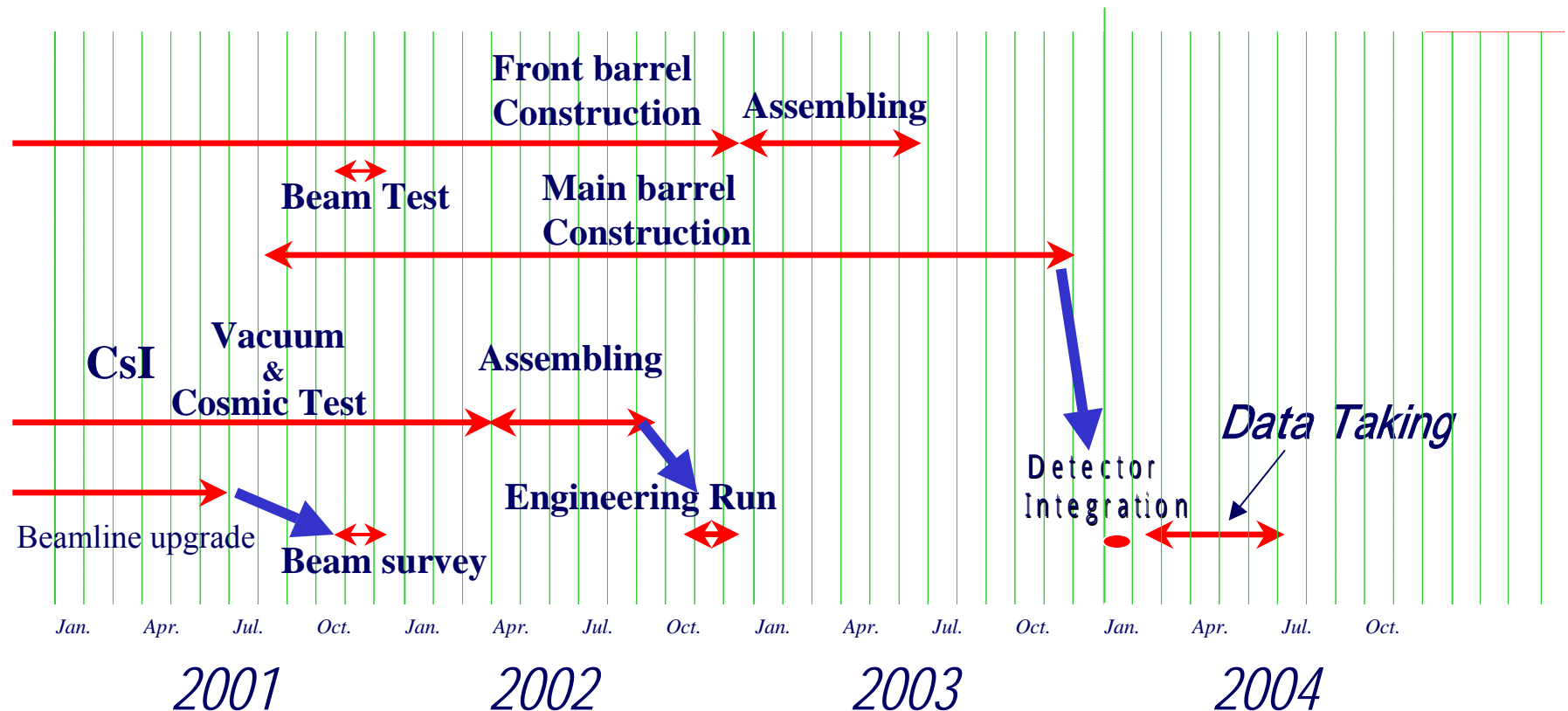


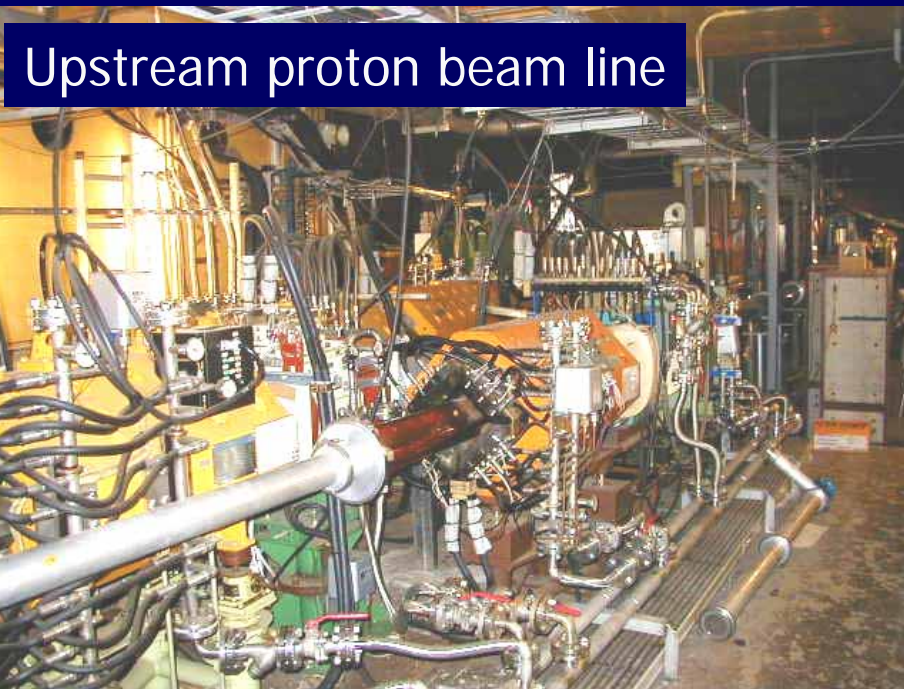
Fig.4

Schedule

Proposal was submitted in 1996.



Upstream proton beam line



Target Station



First Collimators

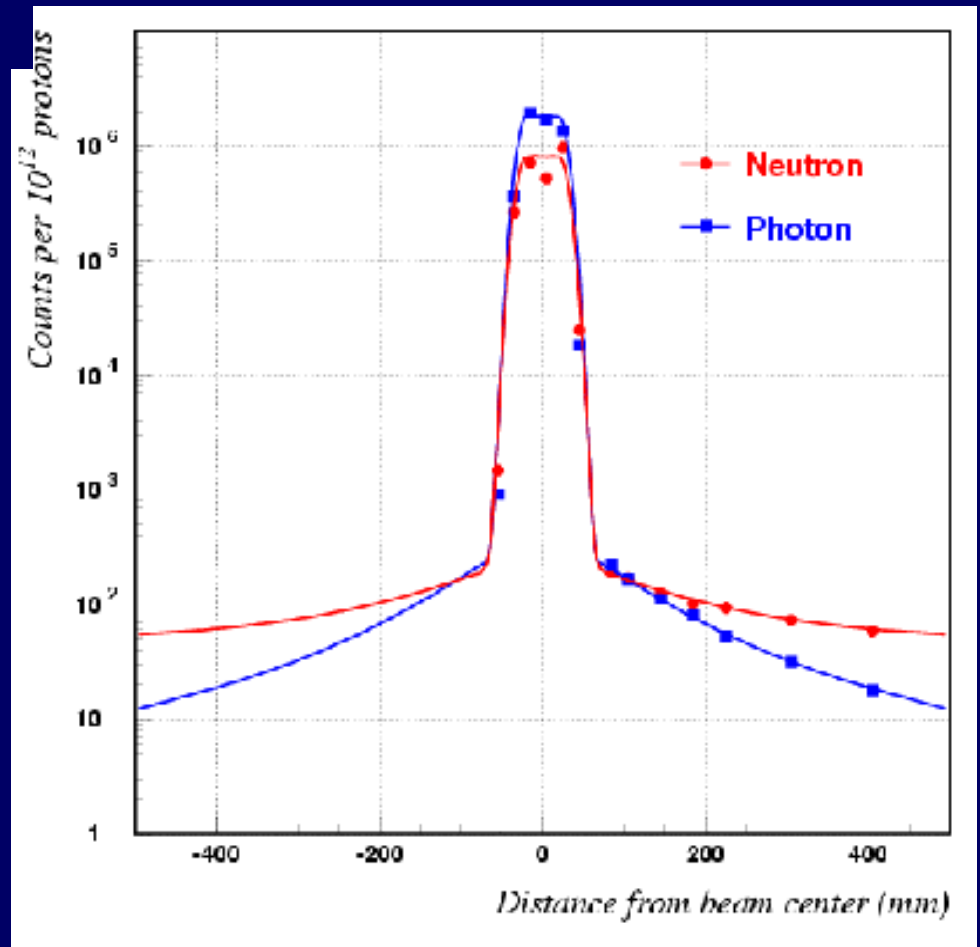
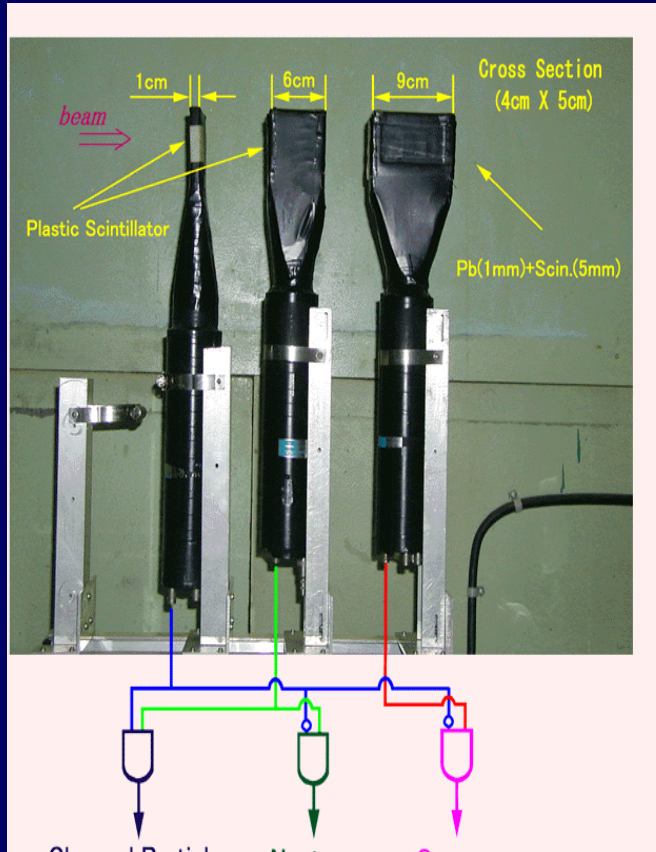


Last Collimators



Beam profile

Counter Telescope



Very Clean !

Detector Construction

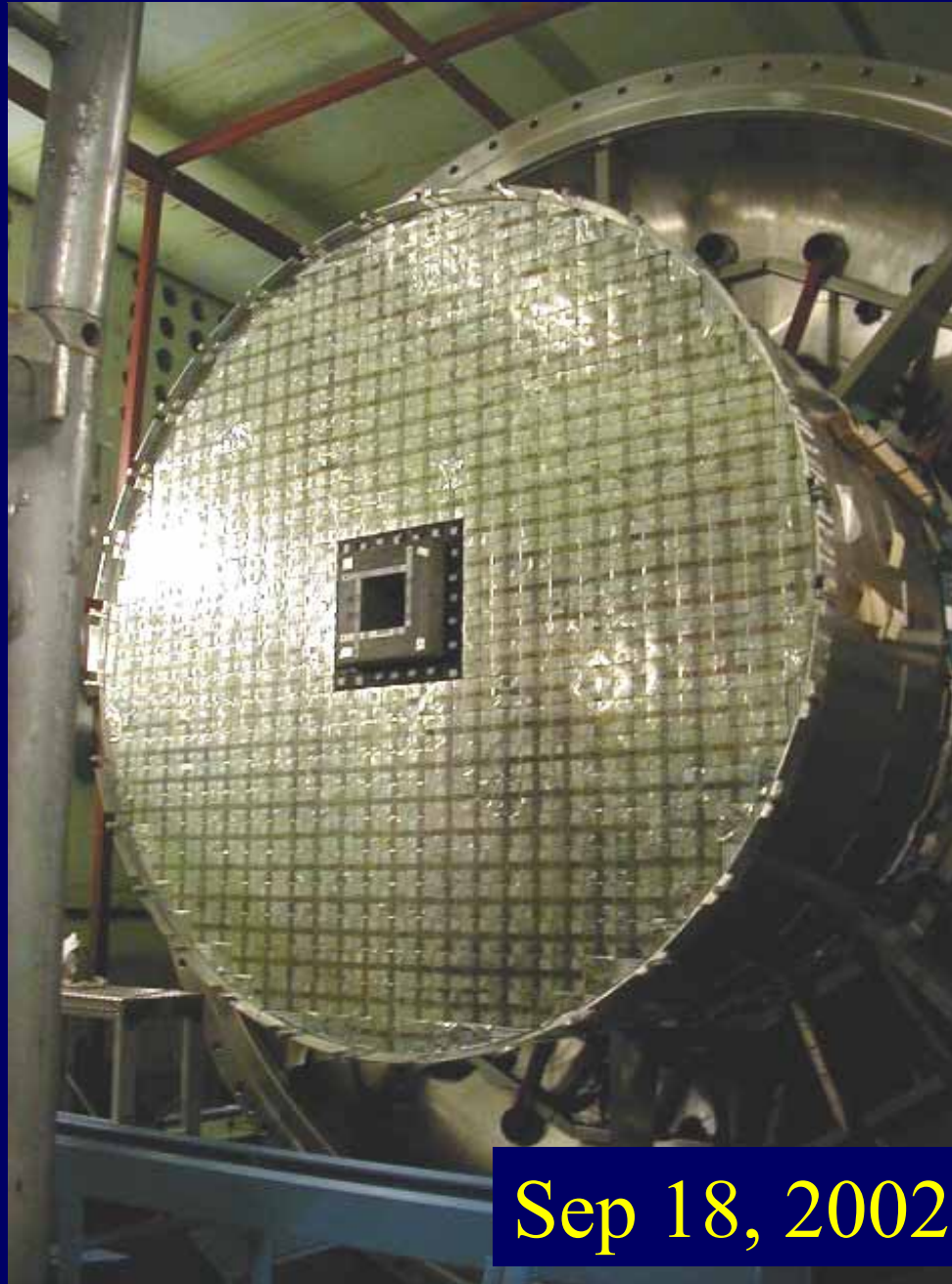
Experimental Area



Downstream Vacuum Vessel



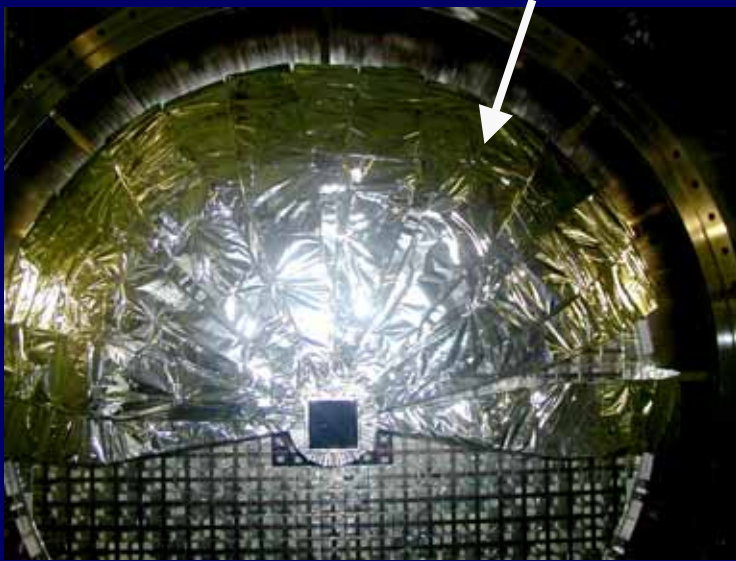
Assembling of CsI calorimeter



Sep 18, 2002

Assembling of Charged-particle Veto

Plastic Scintillator



Engineering Run (Nov - Dec, 2002)

➤ Purpose

➤ Overall check of detector system

➤ Endcap Part (~50% channels)

CsI, Charged-Veto, CC03, BA

DAQ check

→ working property



➤ Electric Noise

➤ Energy Calibration

➤ 1. Cosmic-ray (+ Punch-through muons)

➤ 2. π^0 production by neutron interaction with metal.

➤ Kaon measurement.

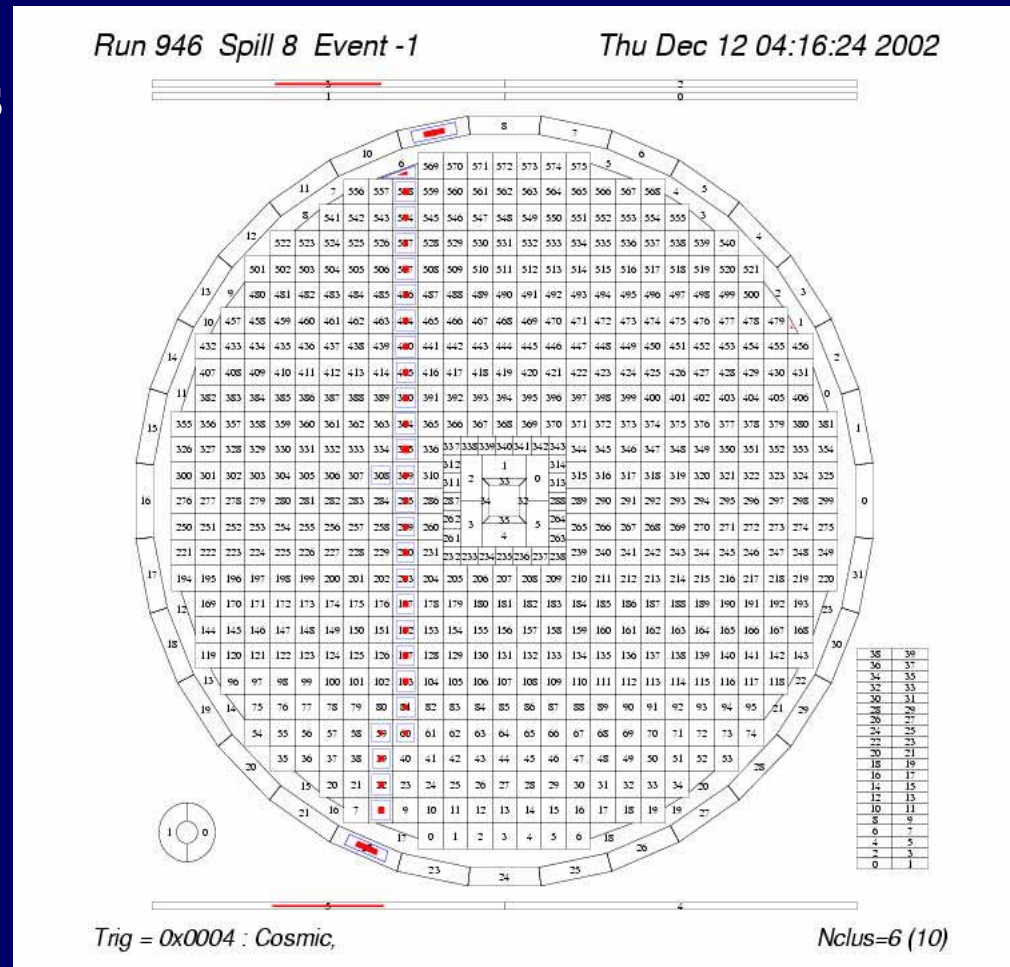
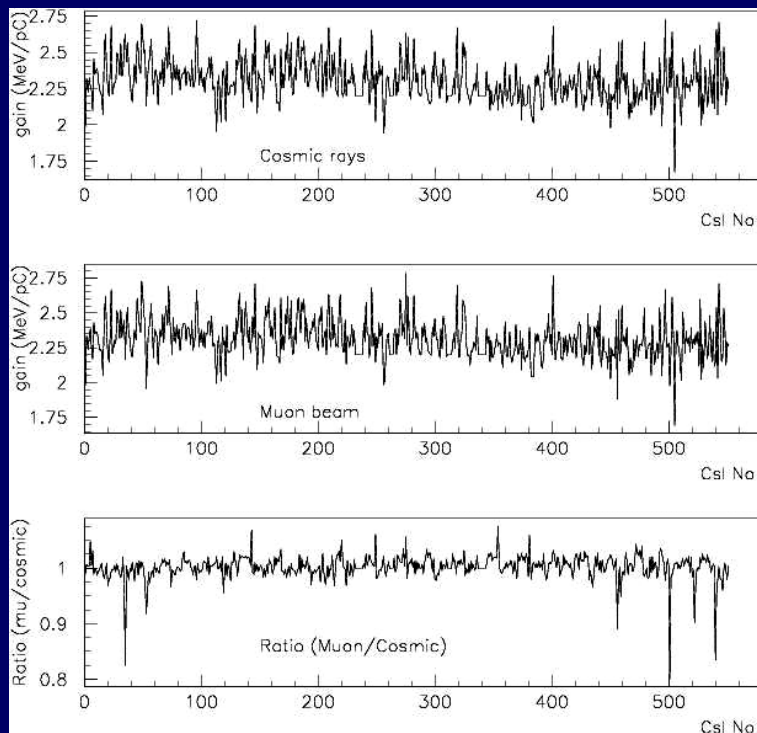
➤ Kaon flux, momentum distribution...etc

Engineering Run

Energy Calibration

Step 1: Cosmic-ray & punch-through muons

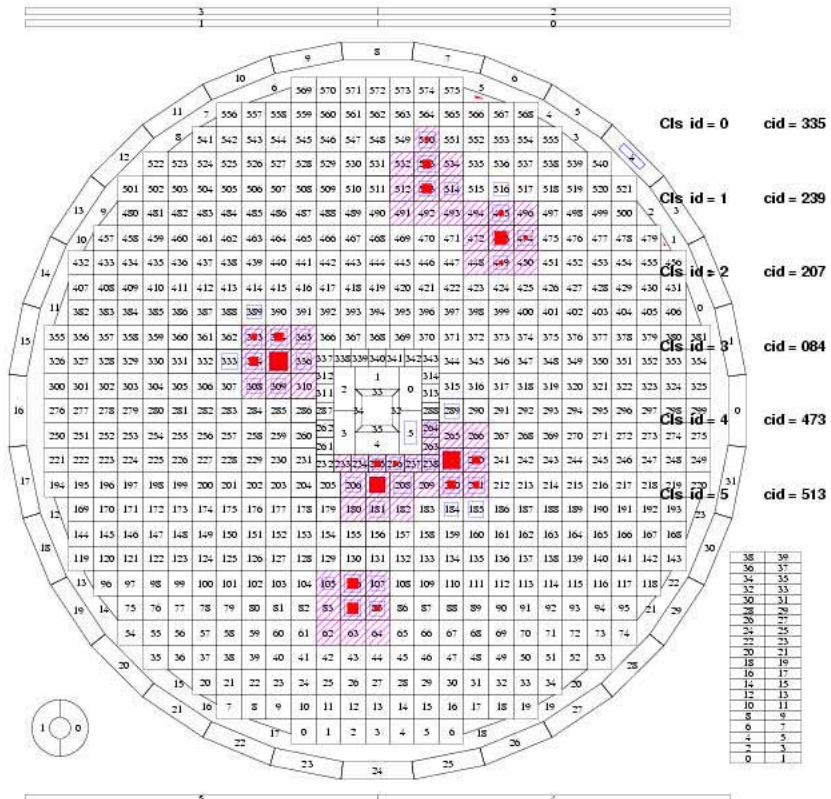
- We can set the gain with accuracy of $\pm 5\%$
- This gain can be used as inputs for next step.



Kaon Run

Run 946 Spill 9 Event 114

Thu Dec 12 04:16:28 2002

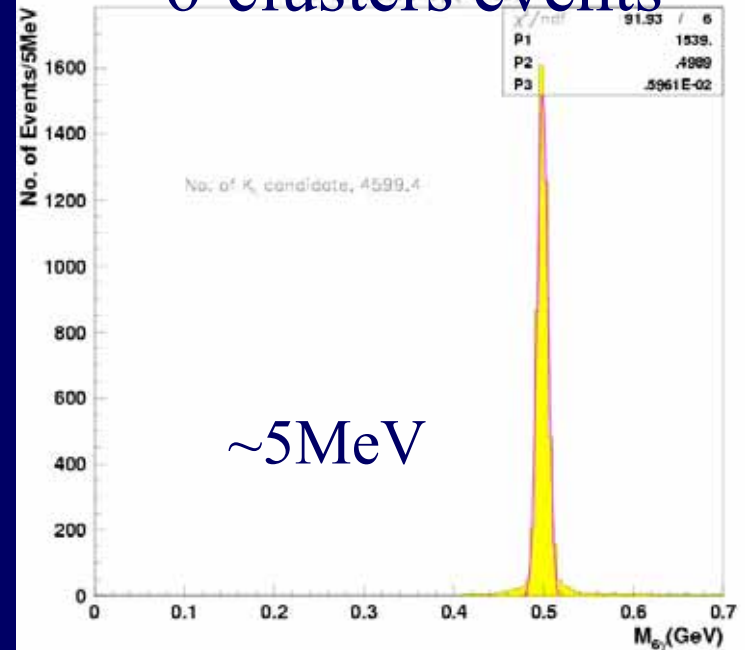


Trig = 0x0011 : OnSpill, Ncluster,

Nclus=9 (9)



6-clusters events



Detector Construction

~ Barrel Part ~

Detector Construction

upstream

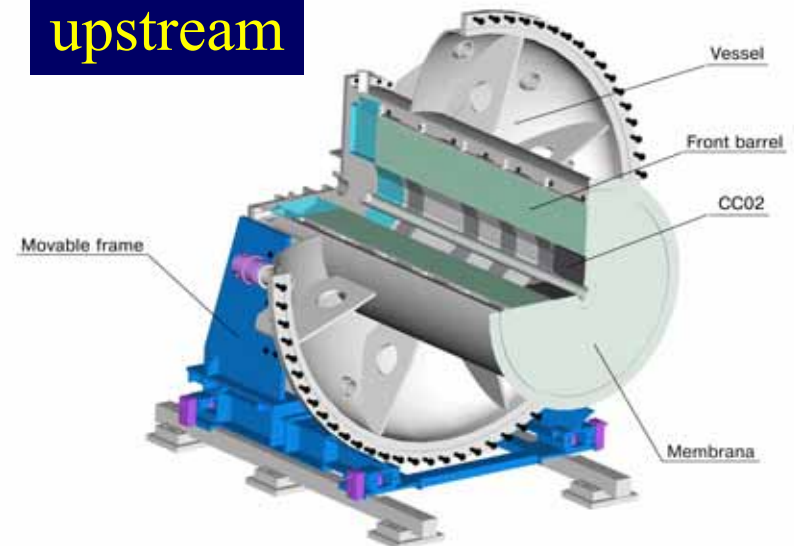
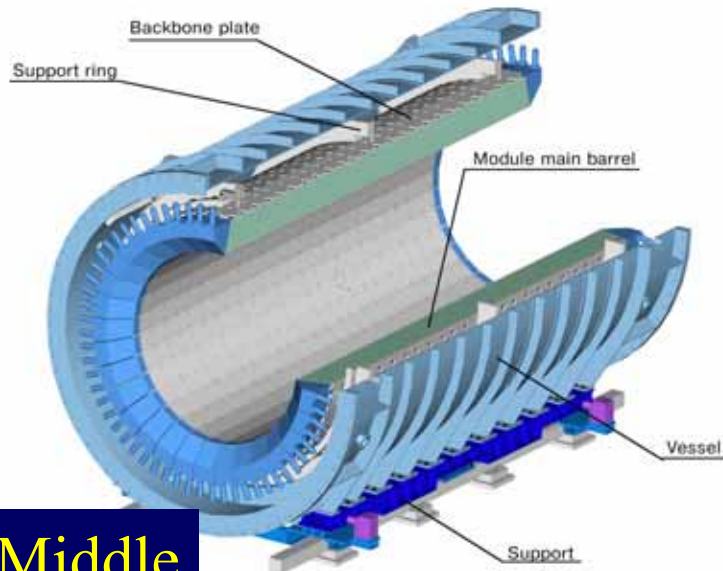


Fig.2



Middle

Fig.3

Downstream

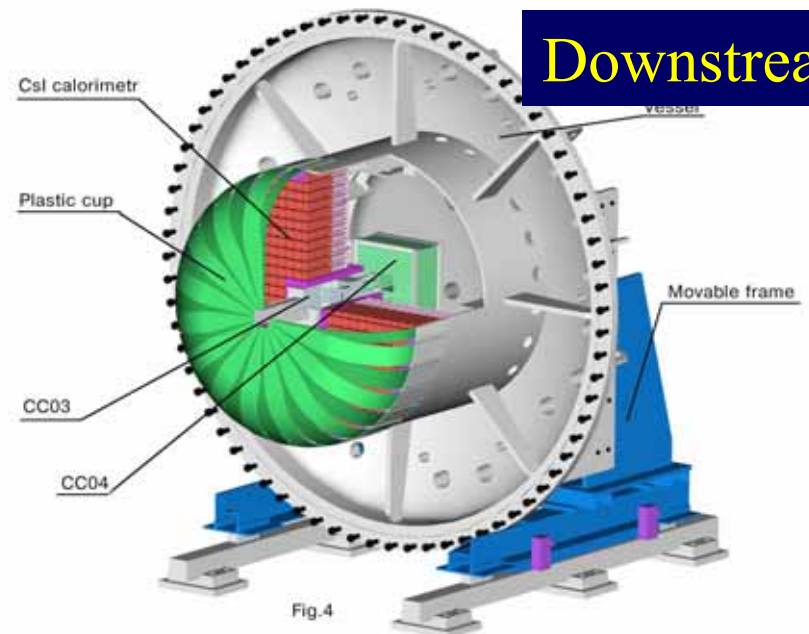
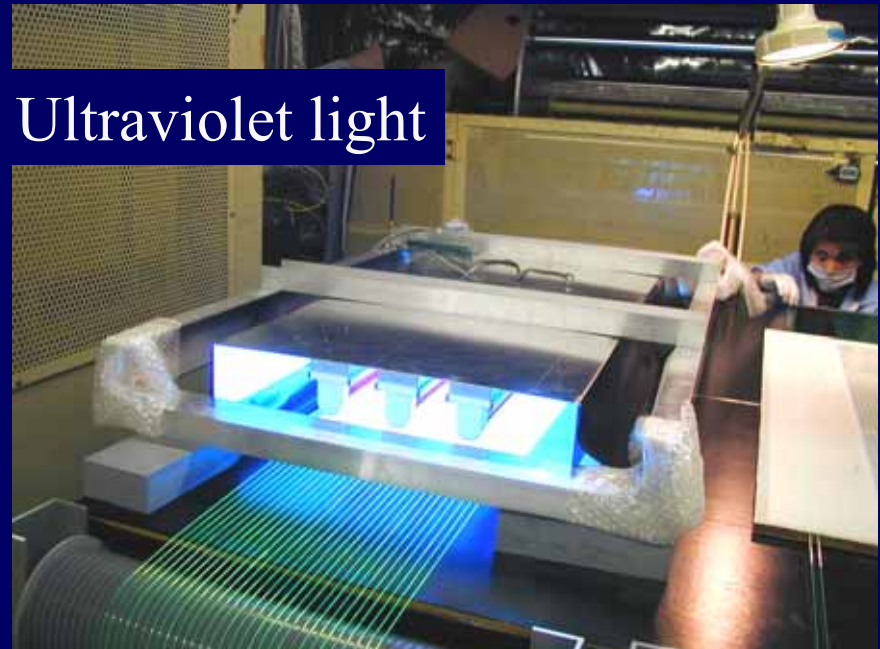
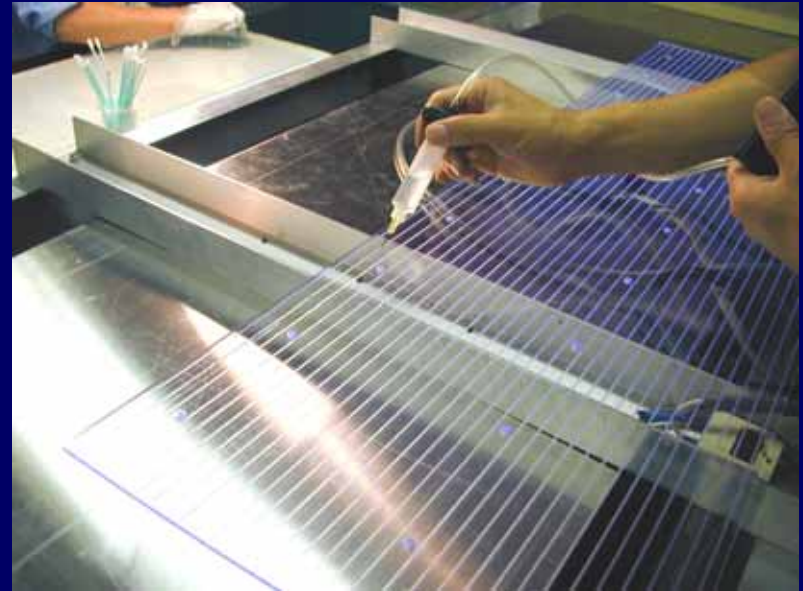
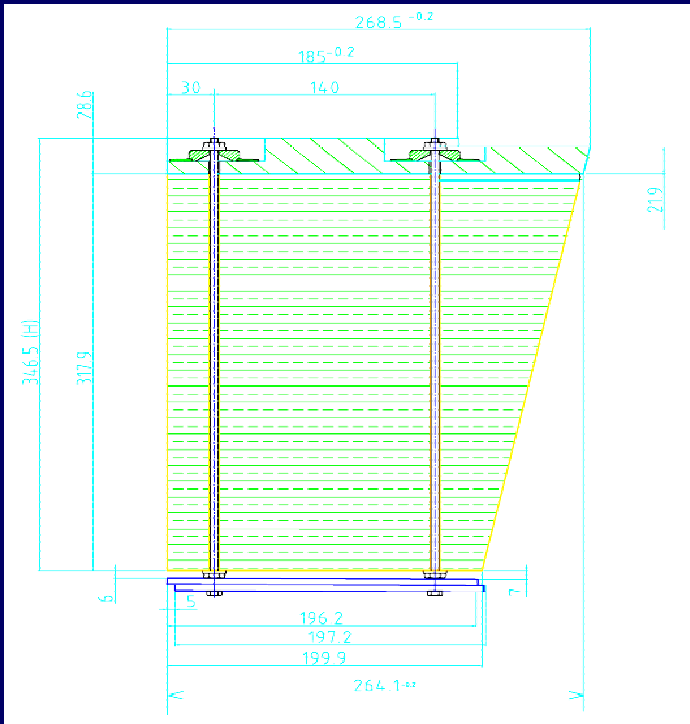


Fig.4

Barrel Fabrication



Ultraviolet light



Fabrication of Front-Barrel Modules



The fabrication of the **Front Barrel** modules : ~Dec 17, 2002.

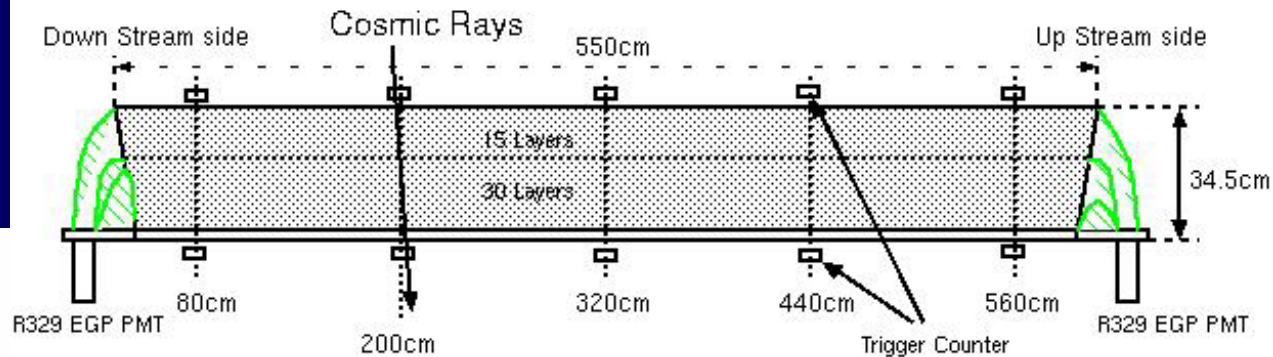
The fabrication of the **Main Barrel** modules : ~Sep 24, 2003.

Barrel-module Fabrication



The fabrication of the **Front Barrel** modules : ~Dec 17, 2002.

The fabrication of the **Main Barrel** modules : ~Sep 24, 2003.



Front Barrel Assembling



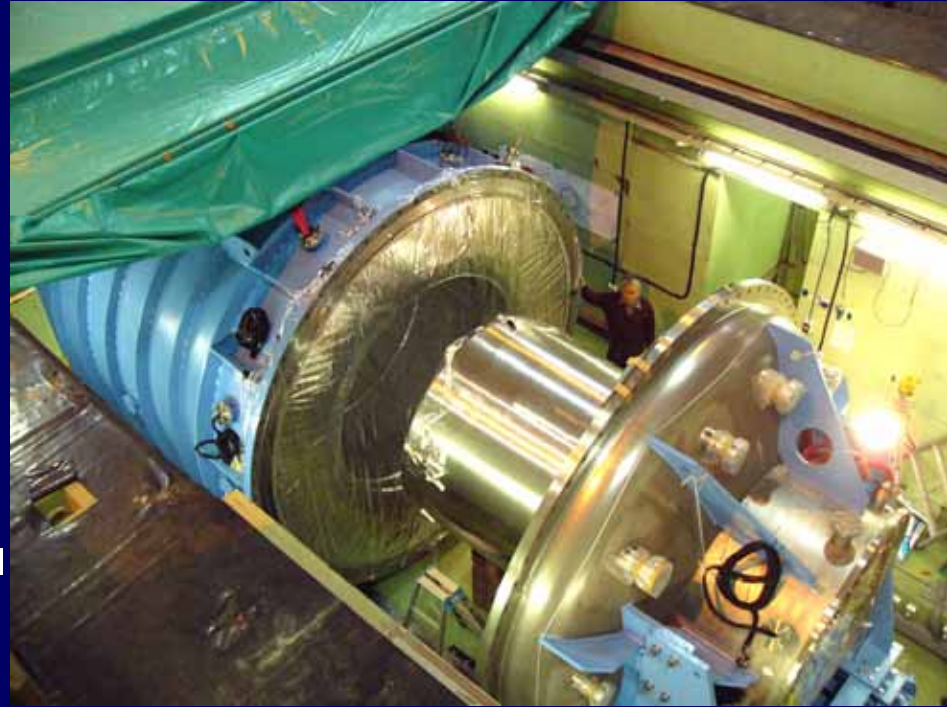
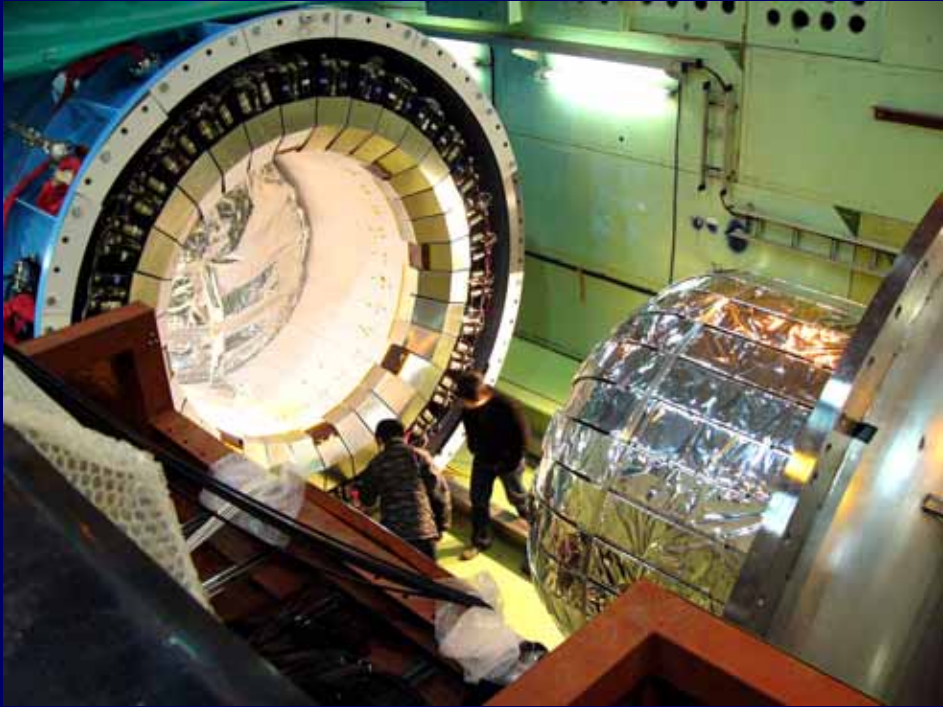
Sep. 5, 2003

Main Barrel Assembling



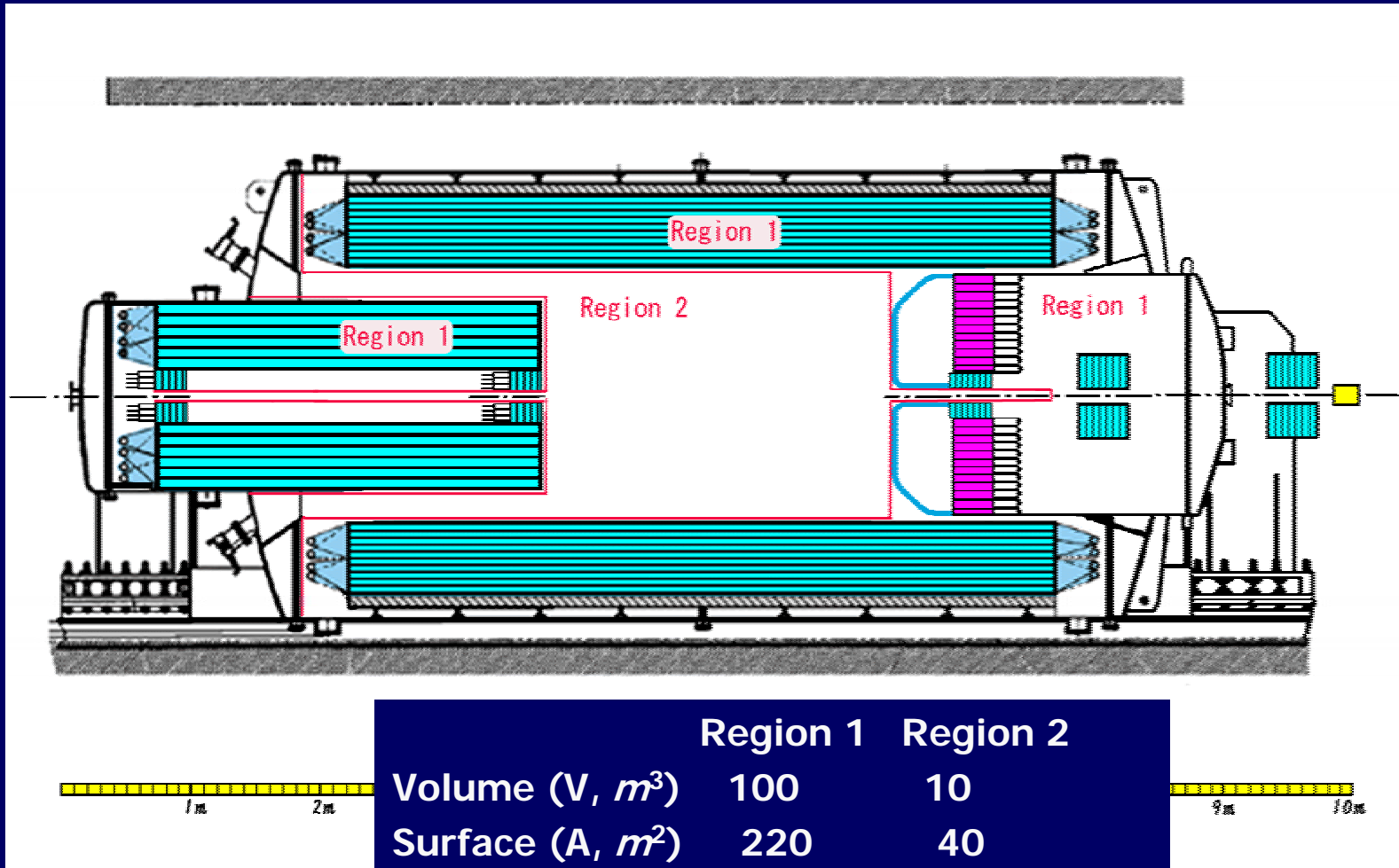
Dec 17, 2003

Detector Integration

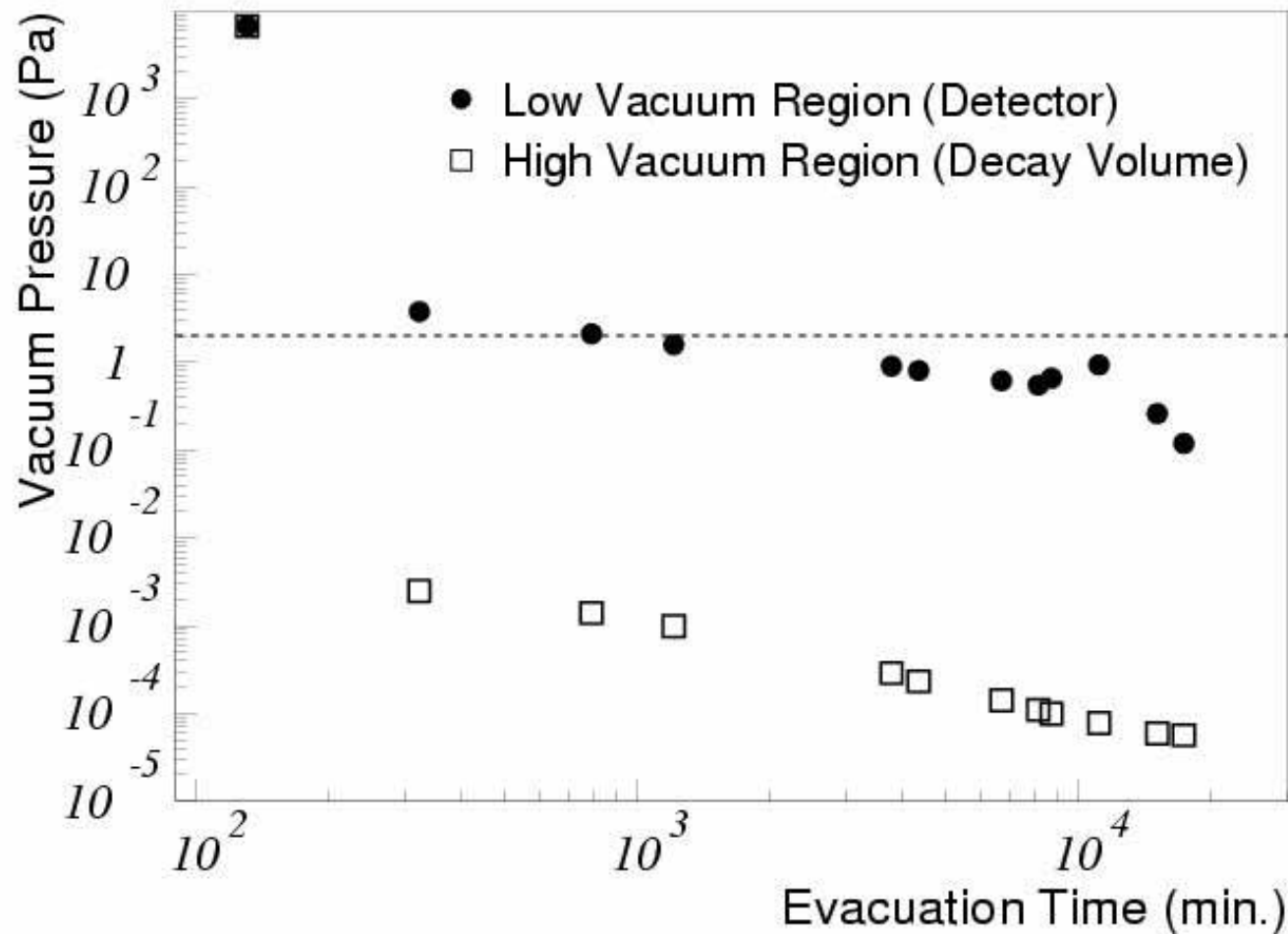
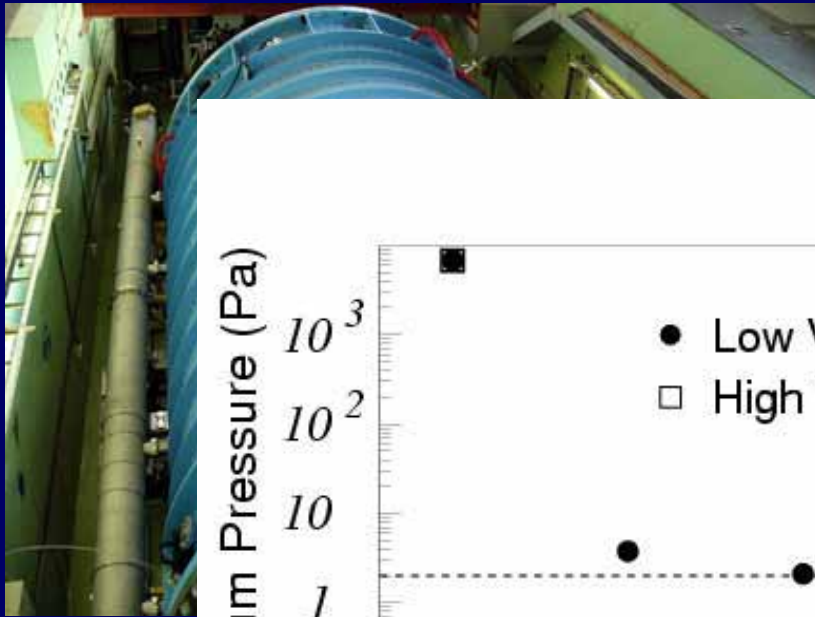


Jan 22, 2004

Vacuum

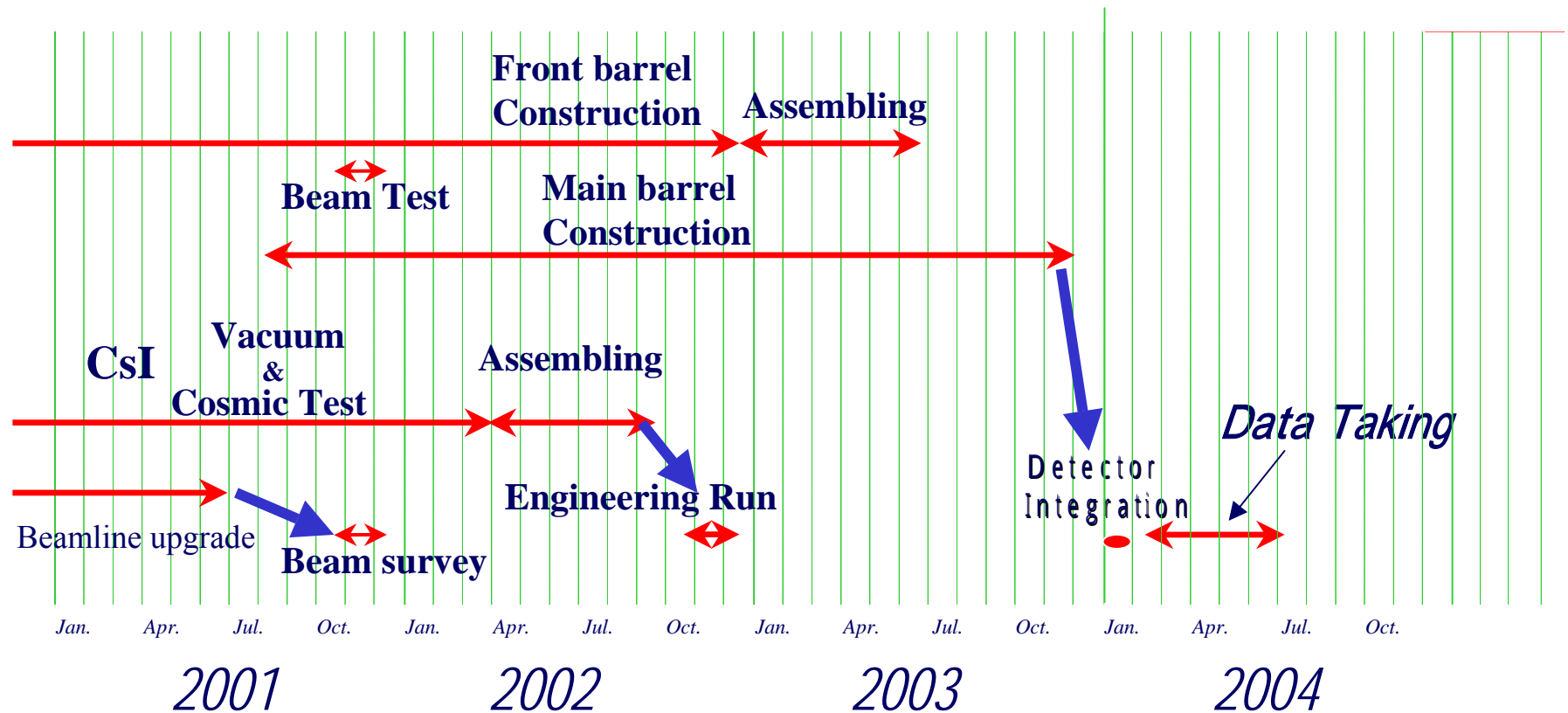


Vacuum



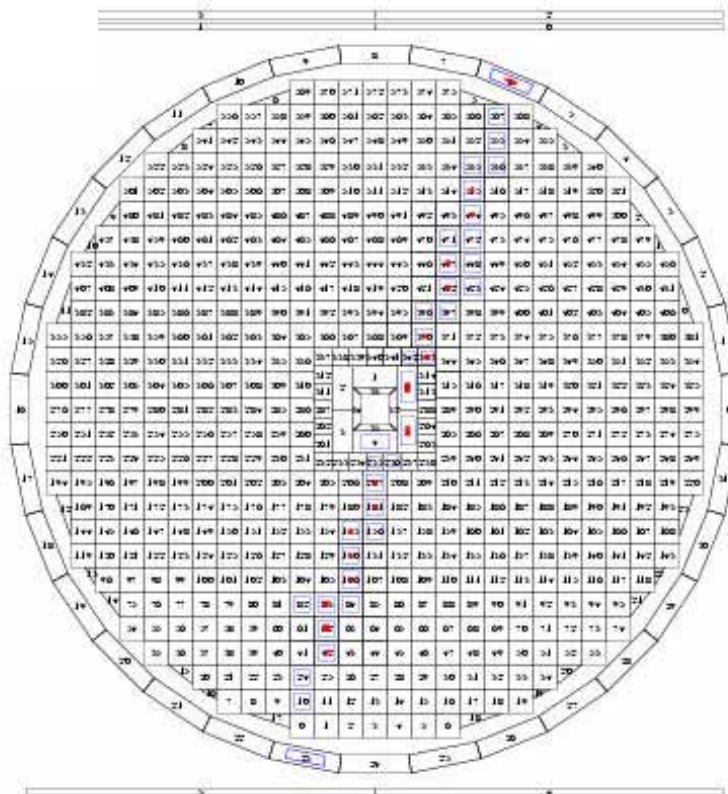
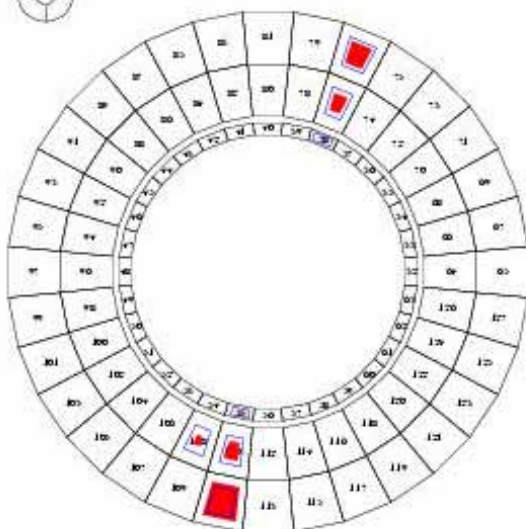
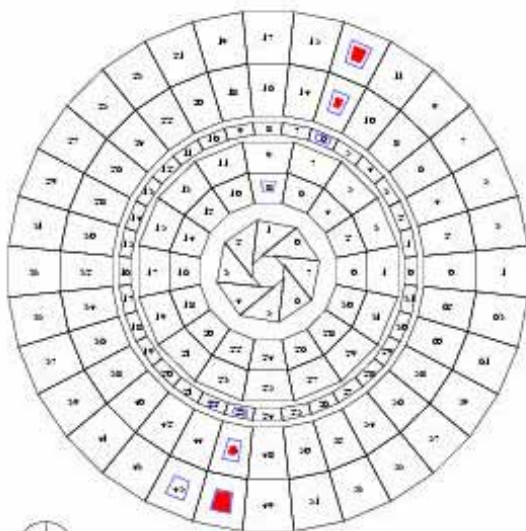
Schedule

Proposal was submitted in 1996.



Cosmic-ray test

-- Nclus=6



CC04

0	1
2	3

CC05

0	1
2	3

CC06

0	1
2	3

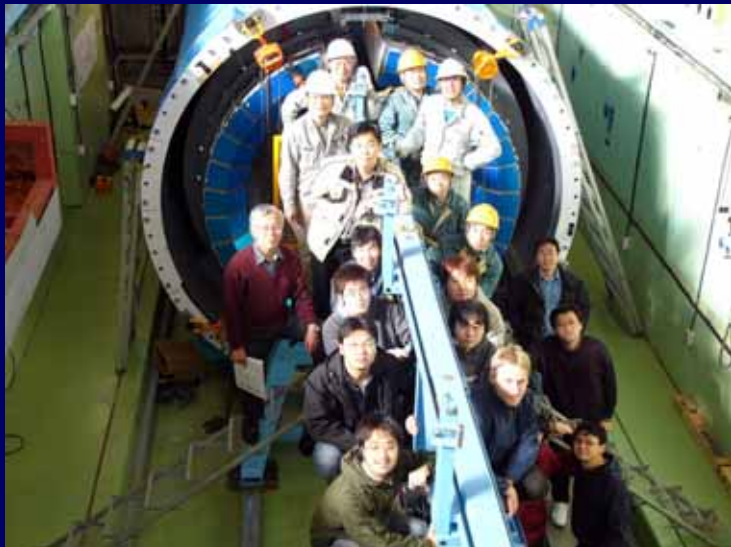
CC07

0	1
2	3

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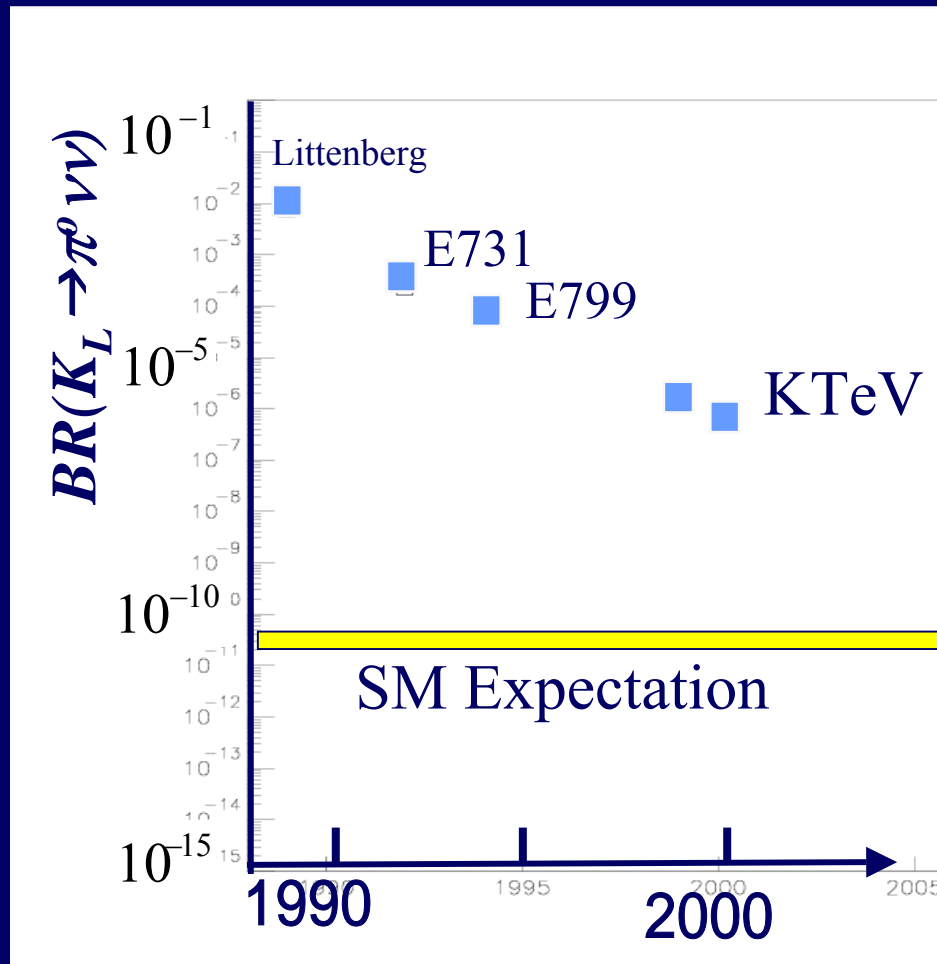
Summary for Status Report その1

- ✧ All detector constructions and its integration were completed !!!
- ✧ All system including Detectors, DAQ and Vacuum are properly working !!!
- ✧ First beam was delivered on Feb. 17th, 2004
 - Status Report その presented by Sugaya-san, Osaka-U

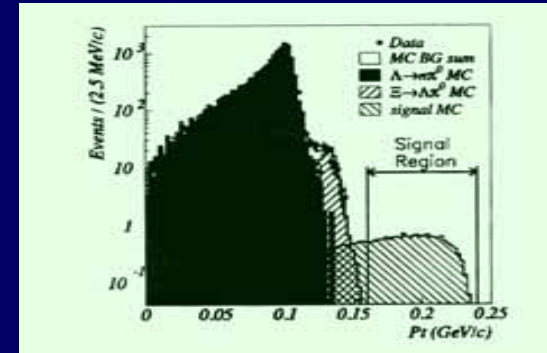


Current Experimental Limit

Search for the $K_L^0 \rightarrow \pi^0 \nu \bar{\nu}$ decay

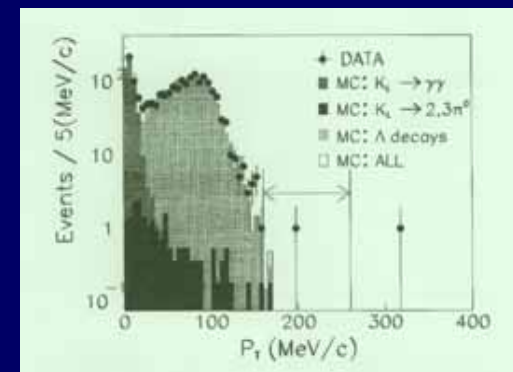


$\pi^0 \rightarrow e^+ e^- \gamma$



Phys. Rev. D61 (2000)

$\pi^0 \rightarrow \gamma \gamma$

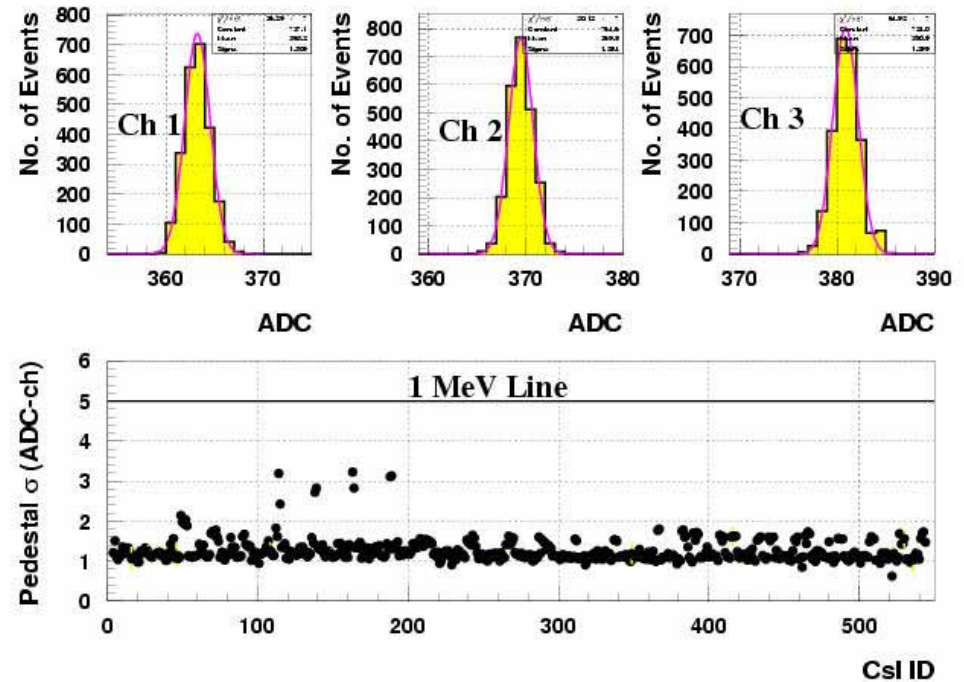


Phys. Lett. B447(1999)

Engineering Run electric noise



Delay cables



50 fC/ADC-ch



CP violation in the Standard Model

$$L = -\frac{g}{\sqrt{2}} \bar{u}_{iL} \gamma^\mu (V_{CKM})_{ij} d_{jL} W_\mu^+ + \text{h.c.}$$

$$CR(L) = -\frac{g}{\sqrt{2}} \bar{u}_{iL} \gamma^\mu (V_{CKM})_{ij}^* d_{jL} W_\mu^+ + \text{h.c.}$$

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix} \cong \begin{bmatrix} 1 - \lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1 - \lambda^2/2 & A\lambda^2 \\ A\lambda^3(1 - \rho - i\eta) & -A\lambda^2 & 1 \end{bmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

★ Standard Model
★ CP Violation

★ →

