Status of the E391a experiment その1

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University of Chicago

Outline

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

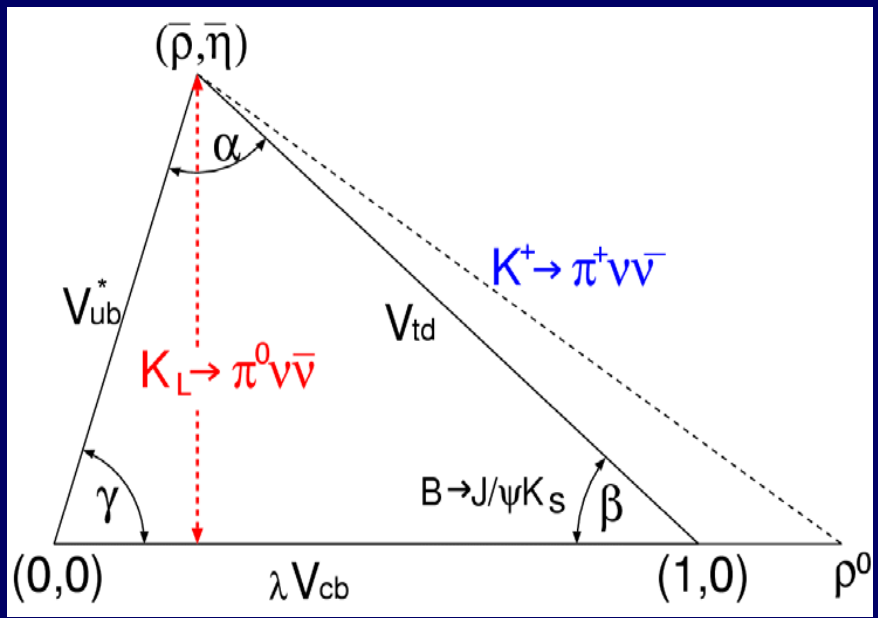
$K^0_L \rightarrow \pi^0 \nu \bar{\nu}$

Theoretical Background

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

$$Br(K_L^0 \to \pi^0 \nu\bar{\nu}) \approx 1.8\times10^{-10} \cdot \eta^2 \approx 3\times10^{-11}$$

- Flavor Changing Neutral Current
- Direct CP violating process ($\Delta s = 1$)
- **Theoretical uncertainty** : Very Small! (~ few % error)
  - The hadron matrix element can be factorized as the well-know $K \to \pi e \nu$ decay!
- One of best tool to determine CP-violation parameter, **η**
- Clue for the new physics

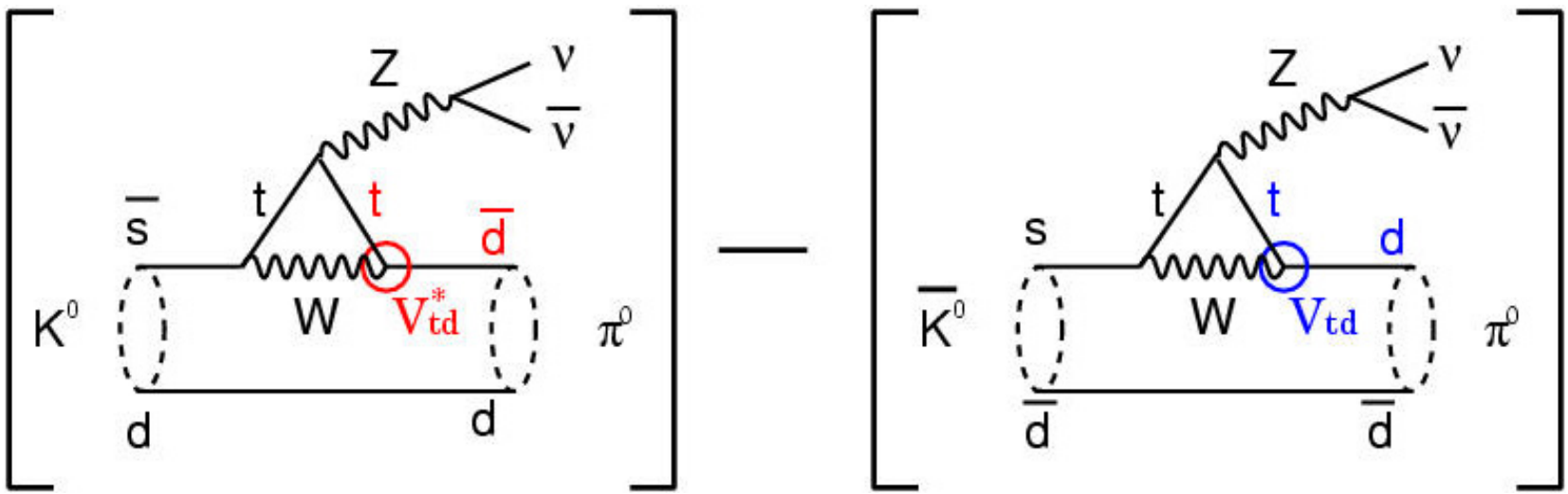


$K_L^0 \to \pi^0 \nu \bar{\nu}$

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

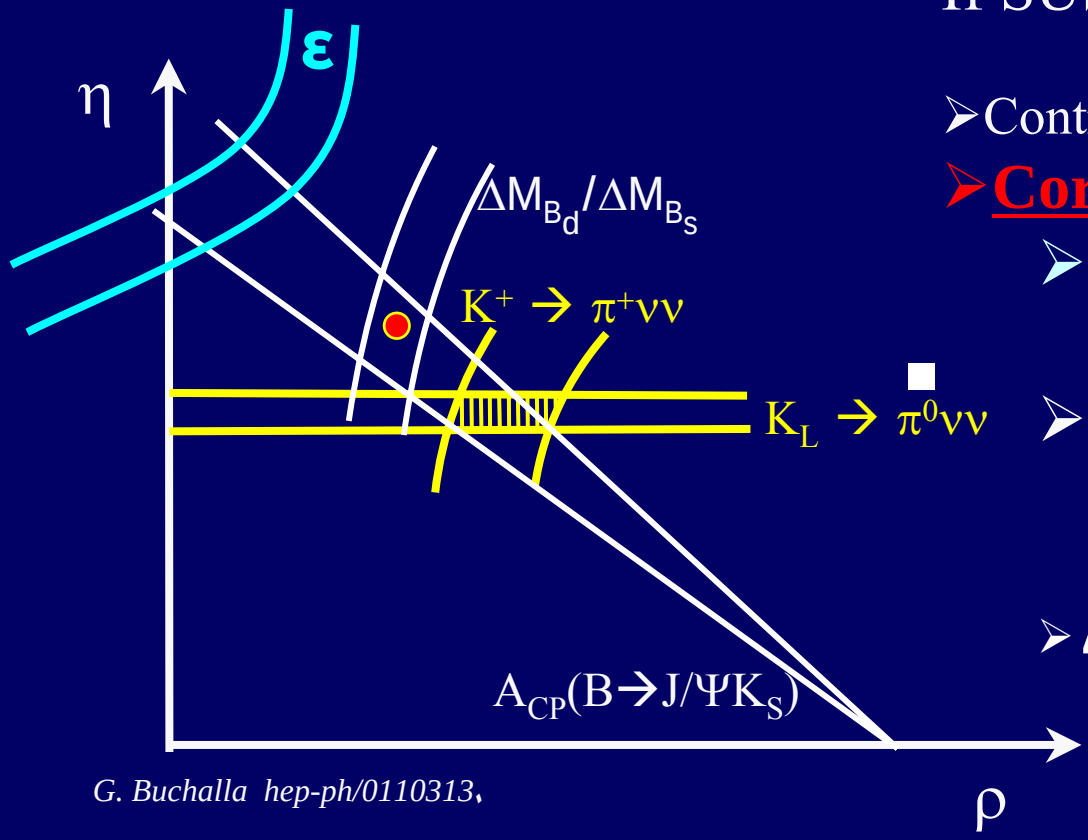
$$\Rightarrow A(K_L^0 \to \pi^0 \nu\bar{\nu}) \approx A(K^0 \to \pi^0 \nu\bar{\nu}) - A(\bar{K}^0 \to \pi^0 \nu\bar{\nu})$$

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



BSM effect

- Unitarity Triangle vertices



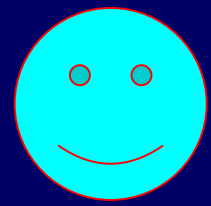
G. Buchalla hep-ph/0110313,

For example:

If SUSY (MSSM) effect exists…

hep-ph/9908499

- Contribution <~10%
- **Correlation**
  - **ε → enhanced**
  - **Br(K→π ν ν) → suppressed**
  - **ΔMBs、A (B→J/ψKs) → unchanged**



These correlations strongly depend on the Model!
Combination of K decays and B decays might give **clue for new physics**

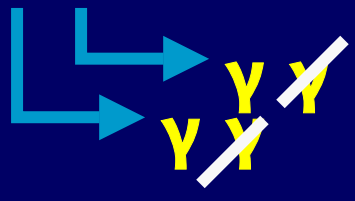
$K^0_L \rightarrow \pi^0 \nu \bar{\nu}$

- Experimentally Challenges

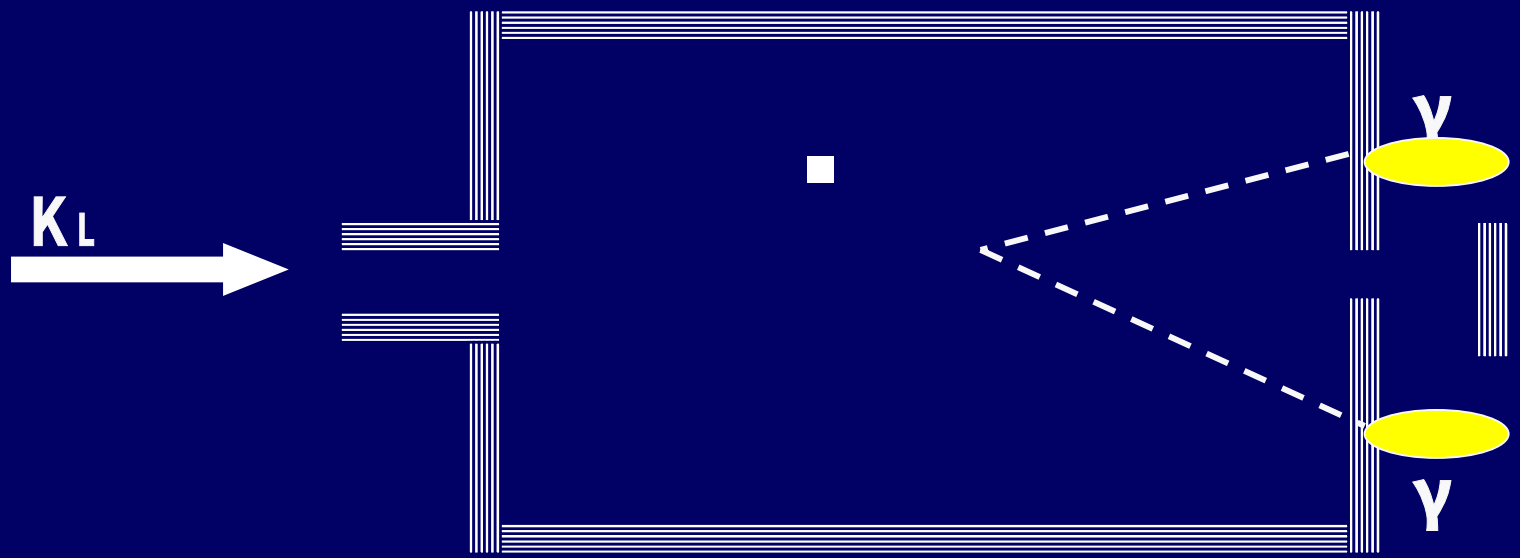
$Br(K_L \to \pi^0 \nu \bar{\nu}) \sim 3 \times 10^{-10}$ ⇒ γ γ + nothing

$Br(K_L \to \gamma \gamma) = 5.86 \times 10^{-5}$ ⇒ γ γ (P_T=0)

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



Pencil Beam(KL) →
Energy, Position of γ ?
→ Decay Vertex, P_T



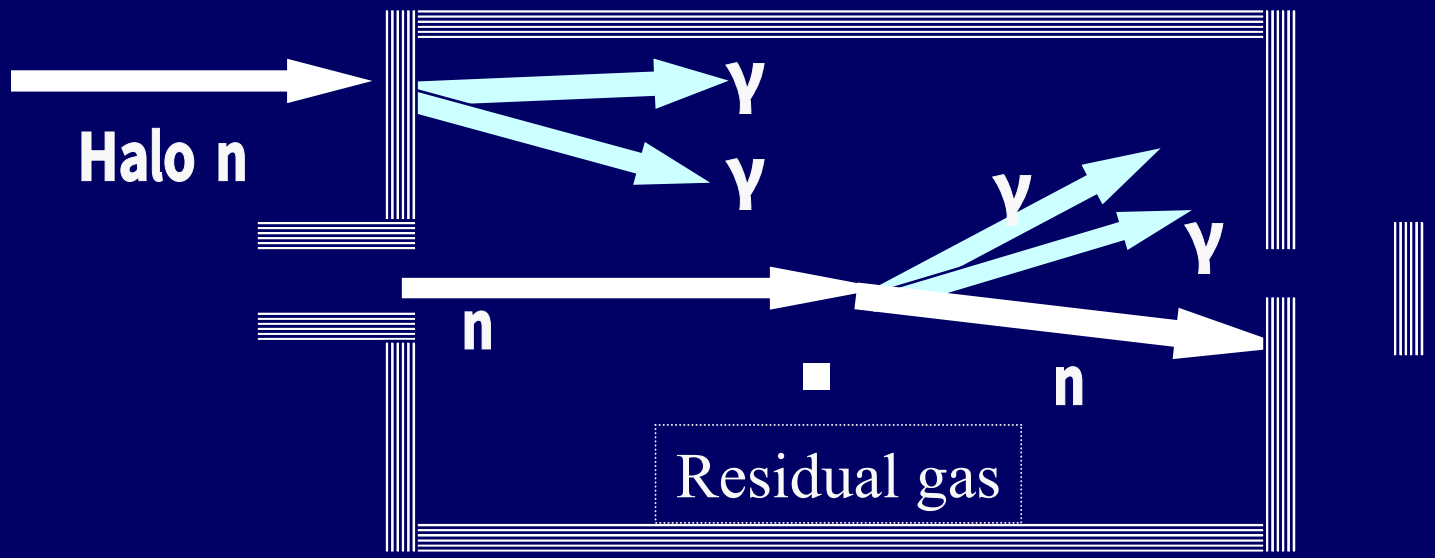
The largest background rejection power :

Veto on extra γ

Detection efficiency ~99.99%

One more things…Beam-related backgrounds

✧Single π^0 is copiously produced by n+n→n+n+π^0



- **Clean beam (beam halo ↓)**
- **Low vacuum pressure 10^{-5} Pa.**

Important Issues

- **Detector**
  - **Highly Hermetic → 4π coverage with thick calorimeter.**
  - **Better γ 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***

R*esearch* ***C****enter for* ***N****uclear* ***P****hysics, Osaka University*

N*ational* ***D****efense* ***A****cademy of* ***J****apan*

J*oint* ***I****nstitute for* ***N****uclear* ***R****esearch (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

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

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

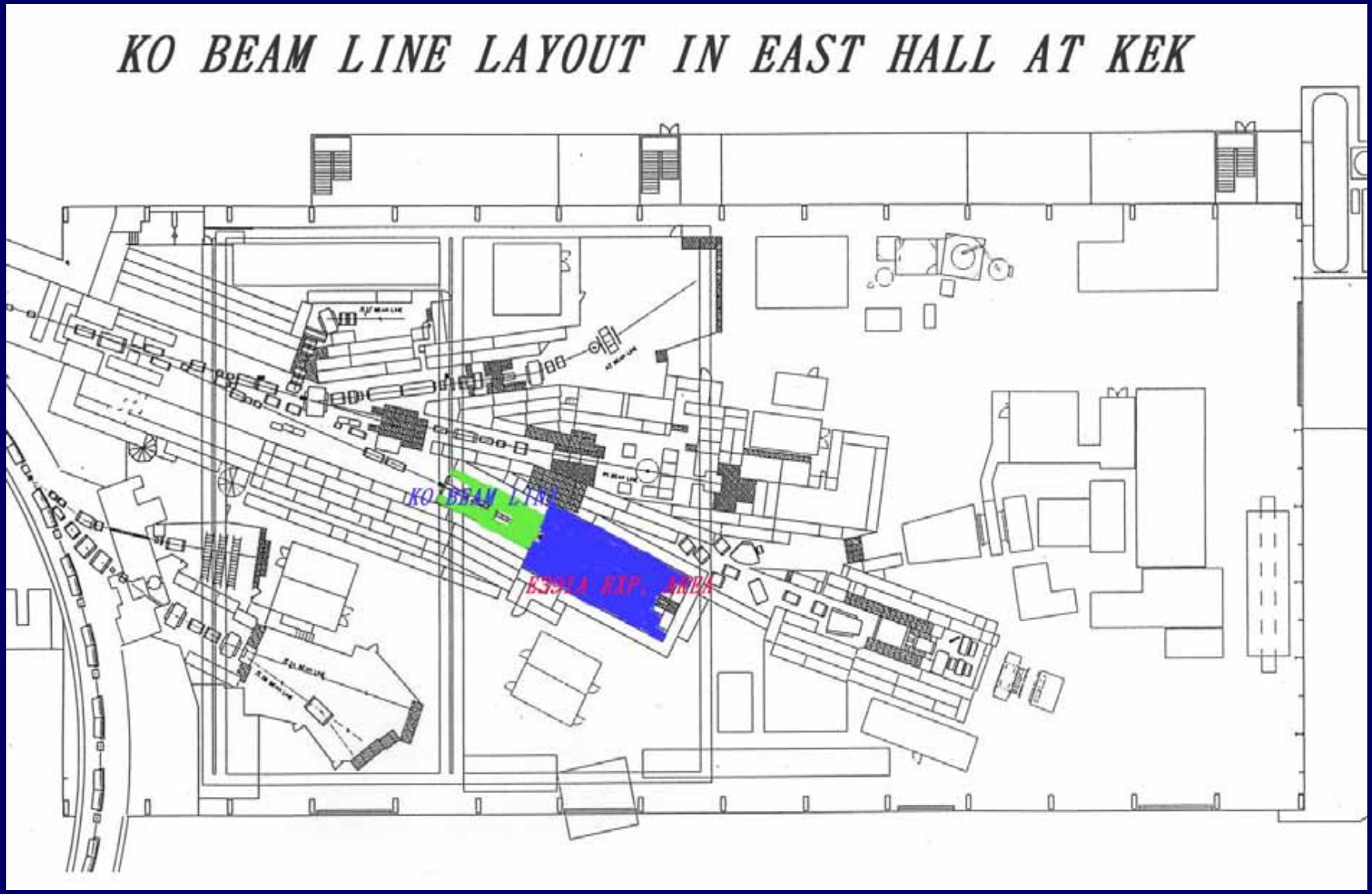
Standard Model prediction : Br $\sim 3 \times 10^{-11}$

Pilot experiment for J-PARC era

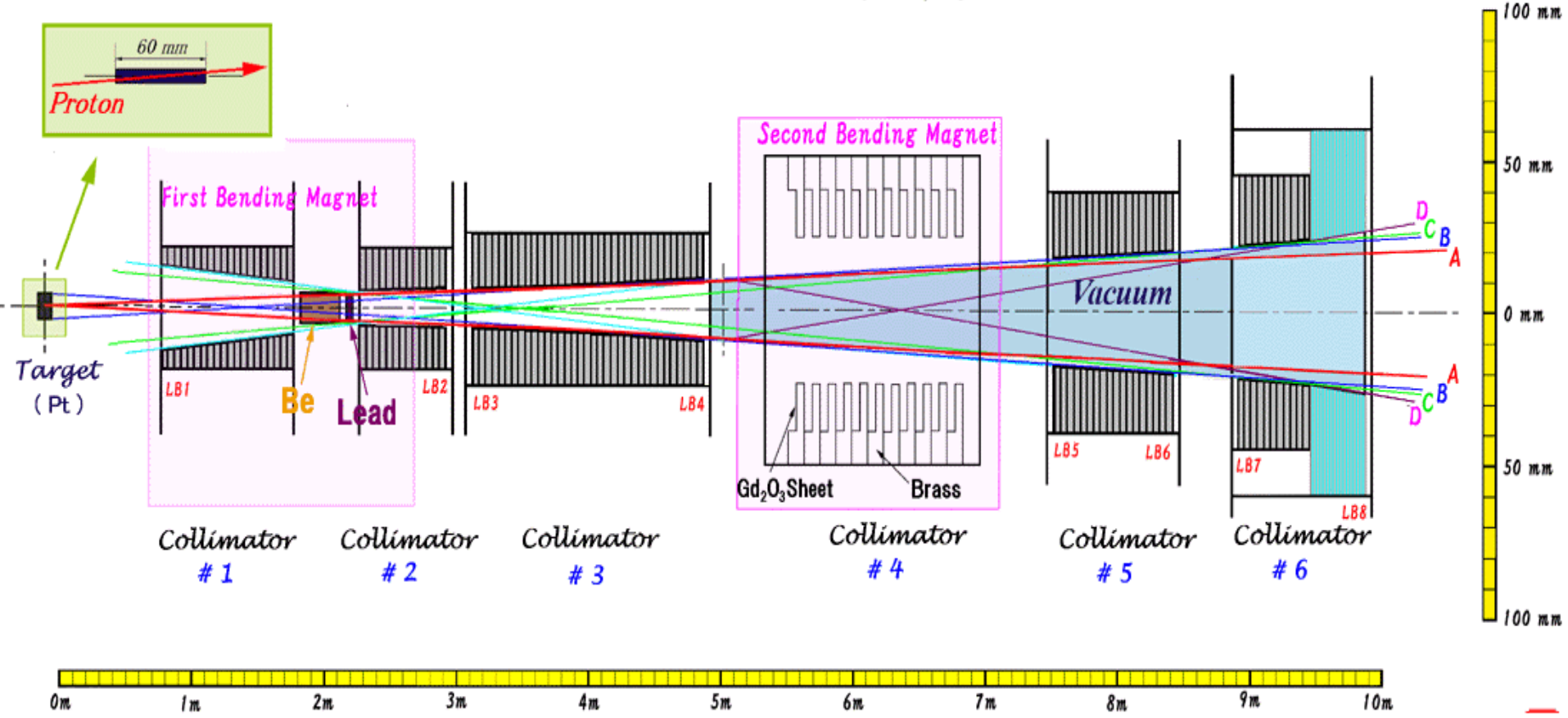
- Verify our method
- Unexpected source of background
- Signatures of backgrounds

- Experiment has been started from Feb. 2004 !

New K0 beam line for E391a

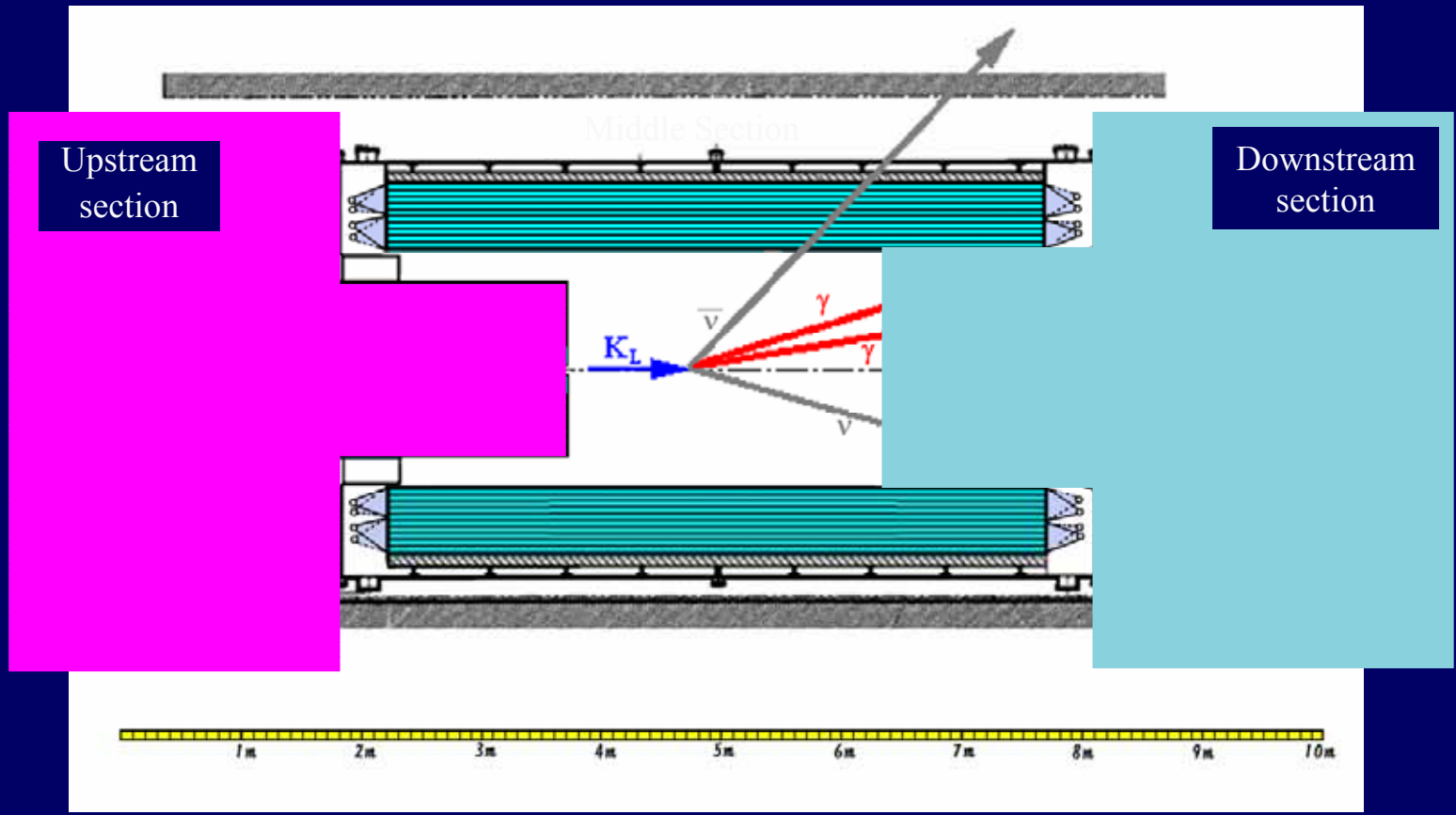


Neutral Beam Line (K0) for E391a



The Construction was finished on March, 2000

E391a Detector Layout



$K_L \rightarrow \pi^o \nu \nu$

$\pi^o \rightarrow \gamma\gamma$ → pure-CsI calorimeter

$\nu \nu$ → *Nothing* → 4π veto system

Upstream

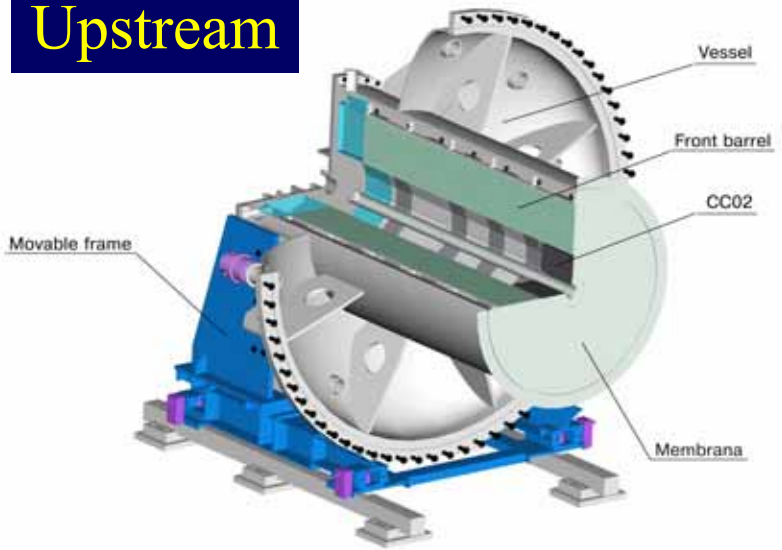


Fig.2

Middle

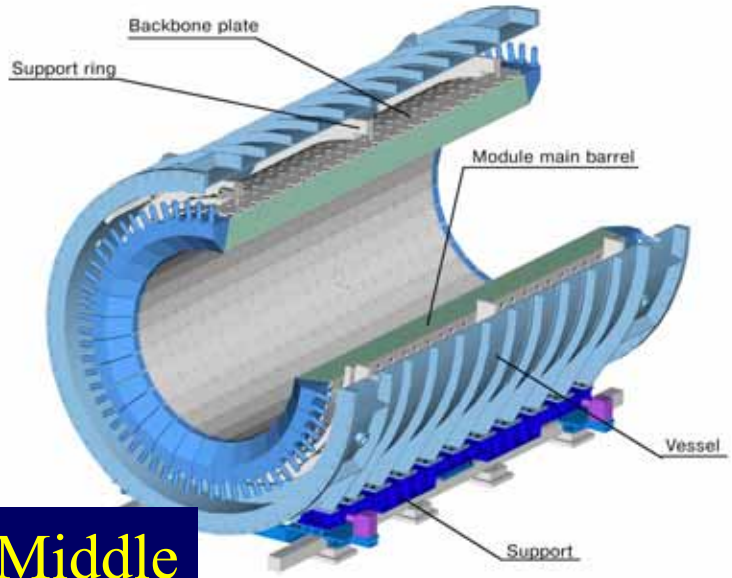


Fig.3

Downstream

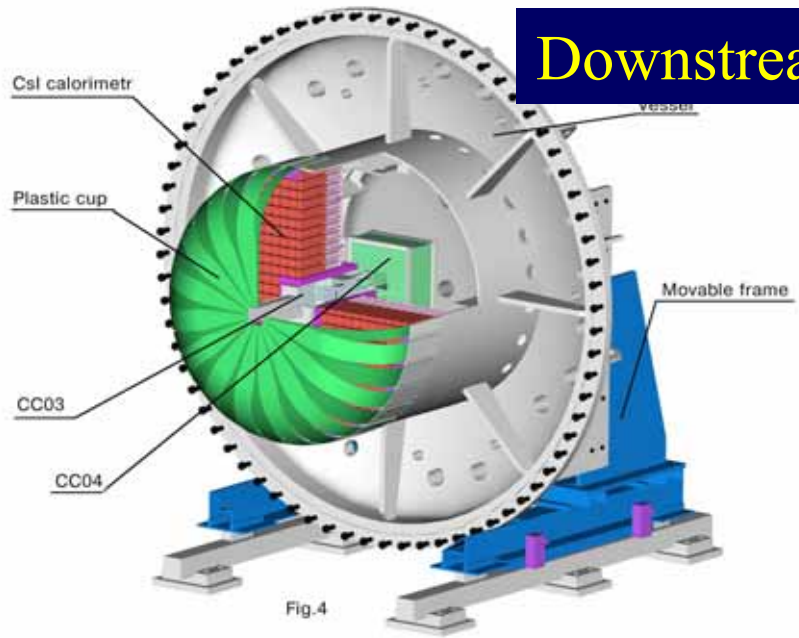
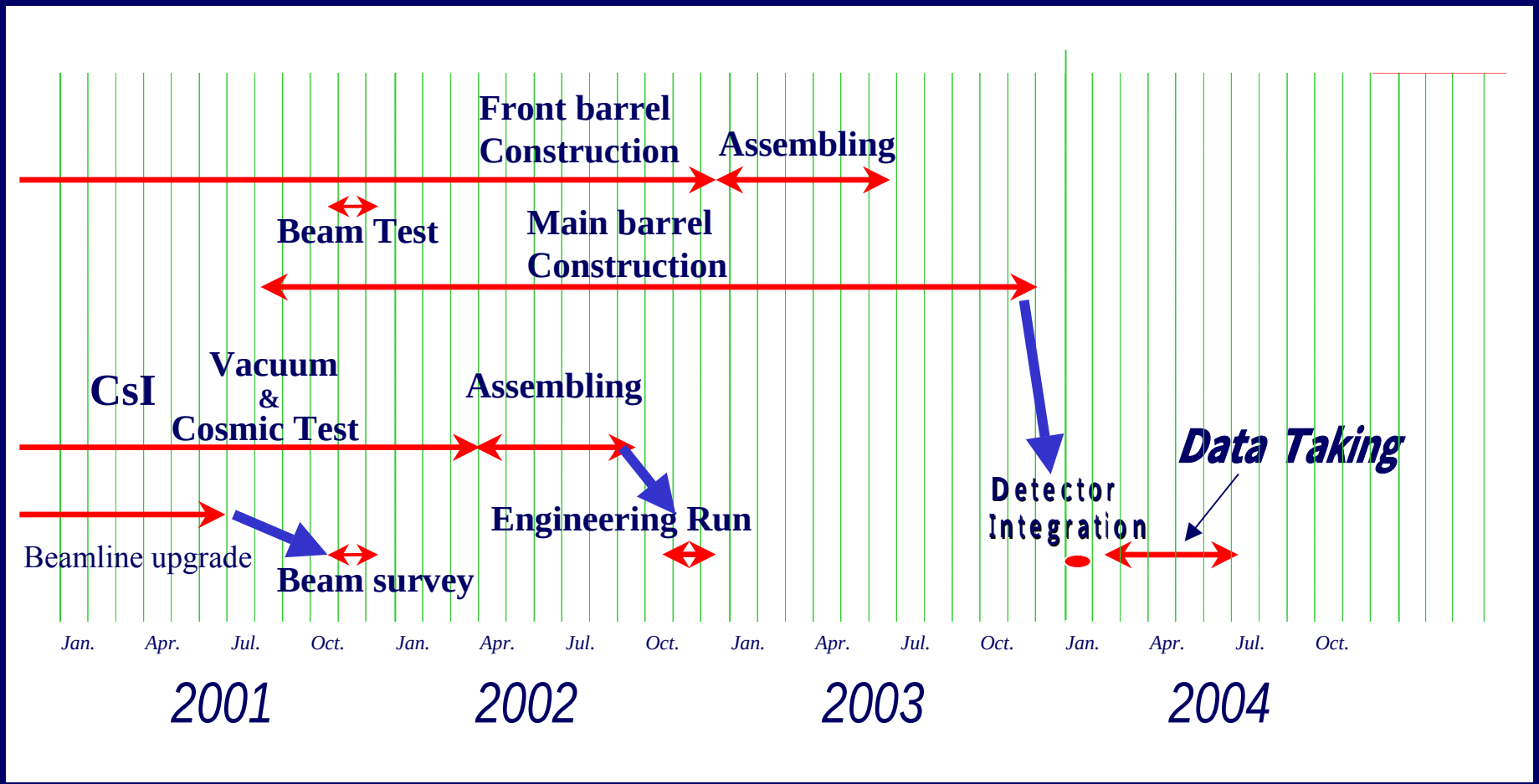


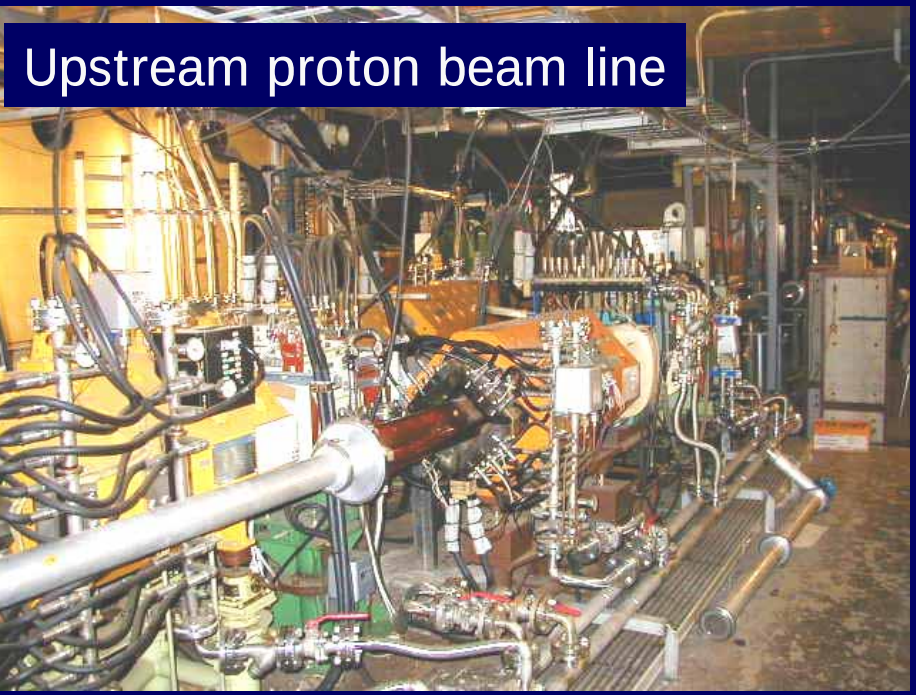
Fig.4

Schedule

Proposal was submitted in 1996.



Upstream proton beam line



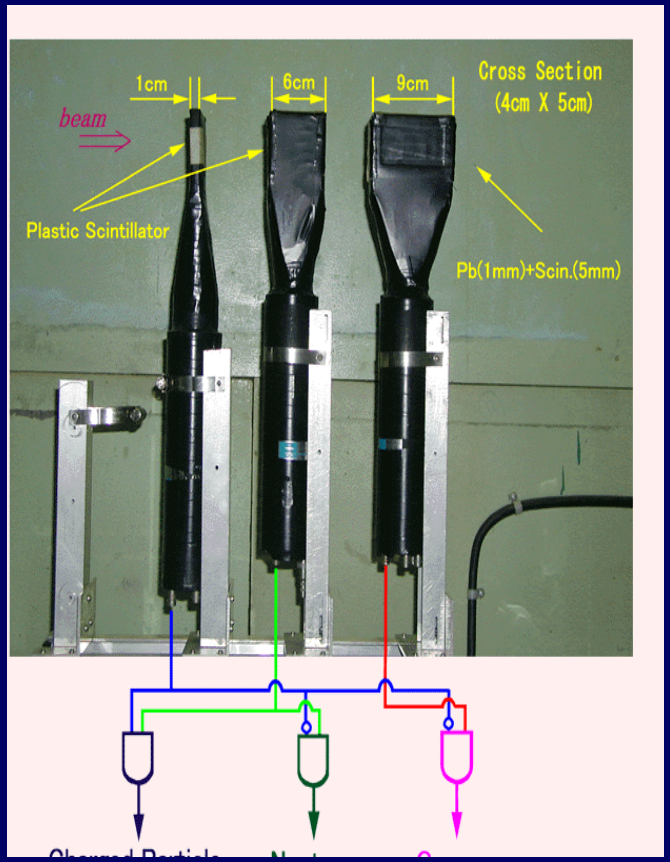
Target Station

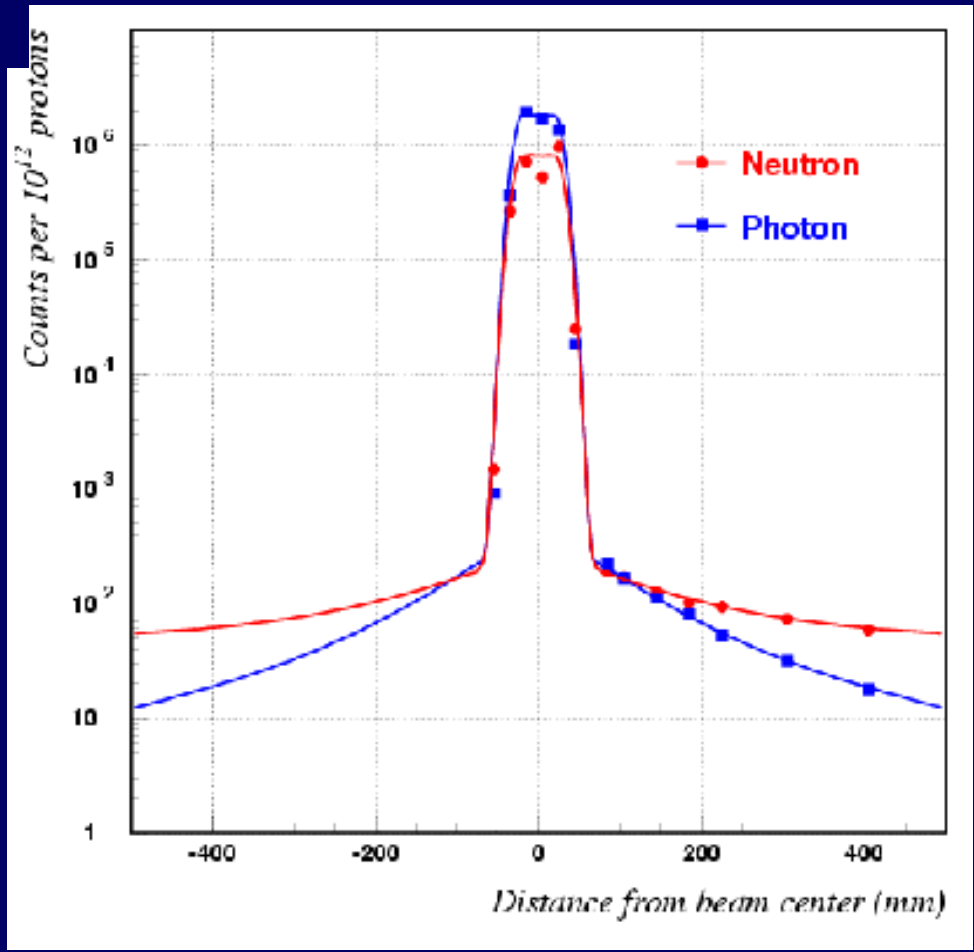
First Collimators

Last Collimators

Beam profile

Counter Telescope





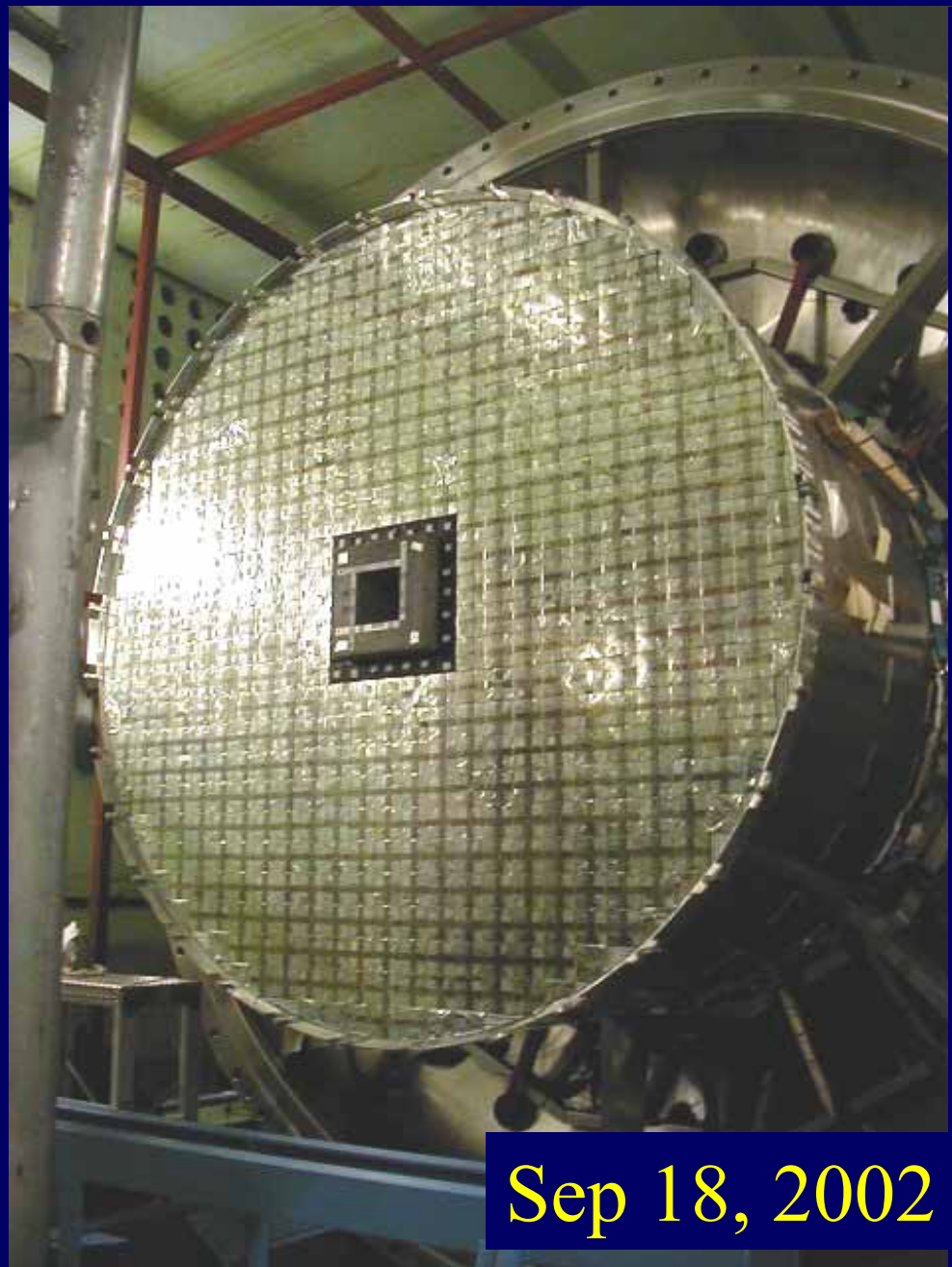
Very Clean !

Detector Construction

Experimental Area

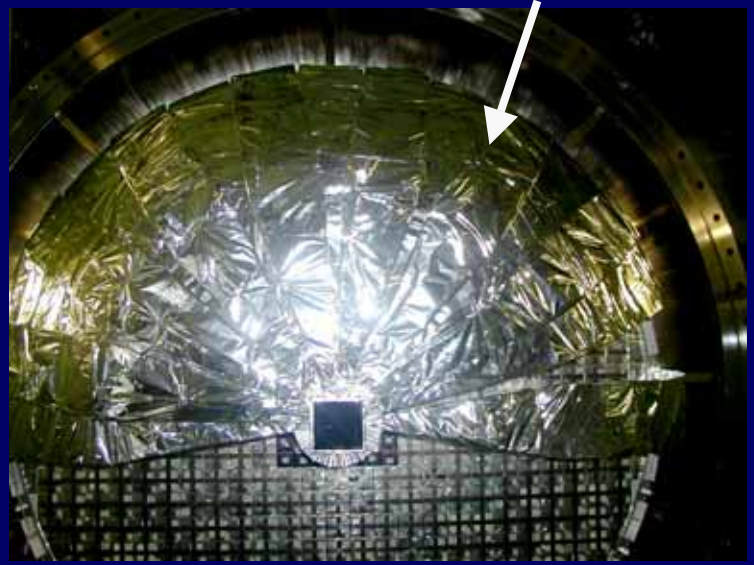
Downstream Vacuum Vessel

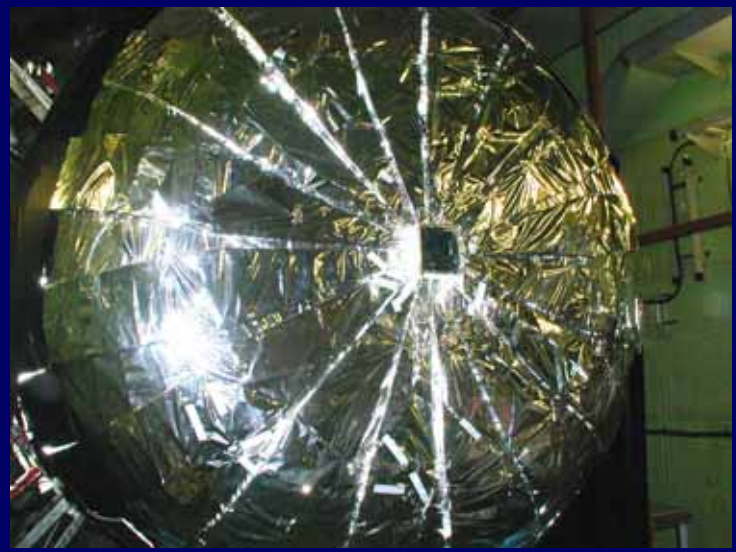
Assembling of CsI calorimeter



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

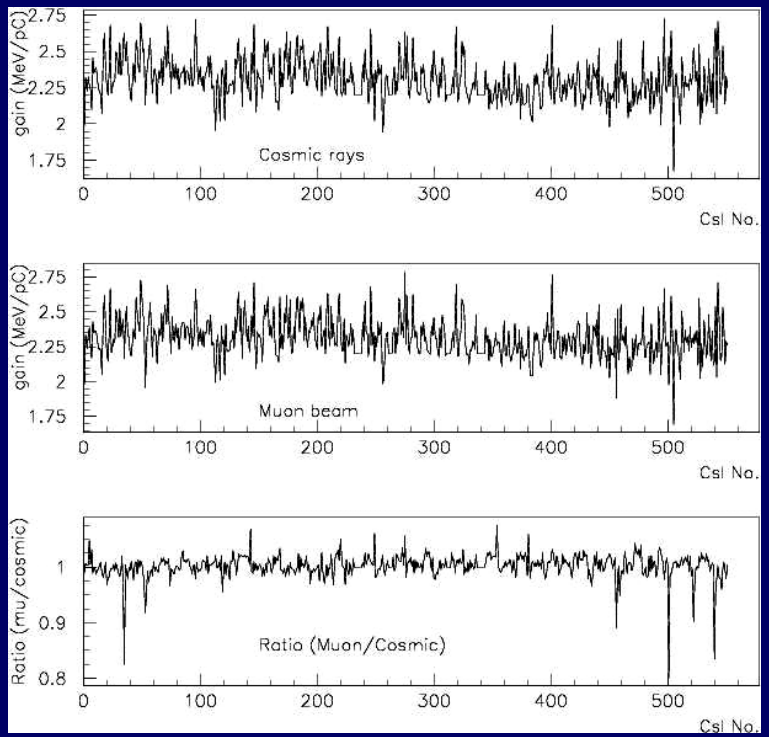
Engineering Run

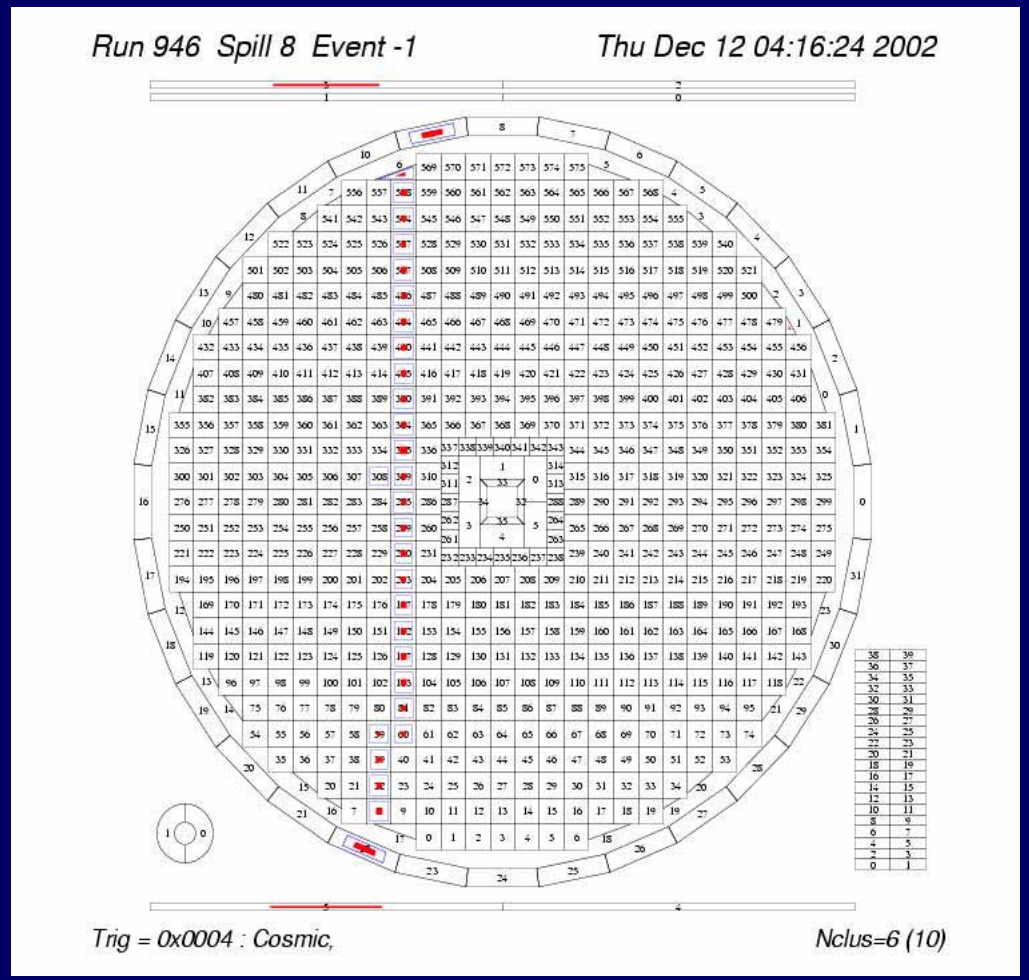
Energy Calibration

Step 1: Cosmic-ray & punch-through muons

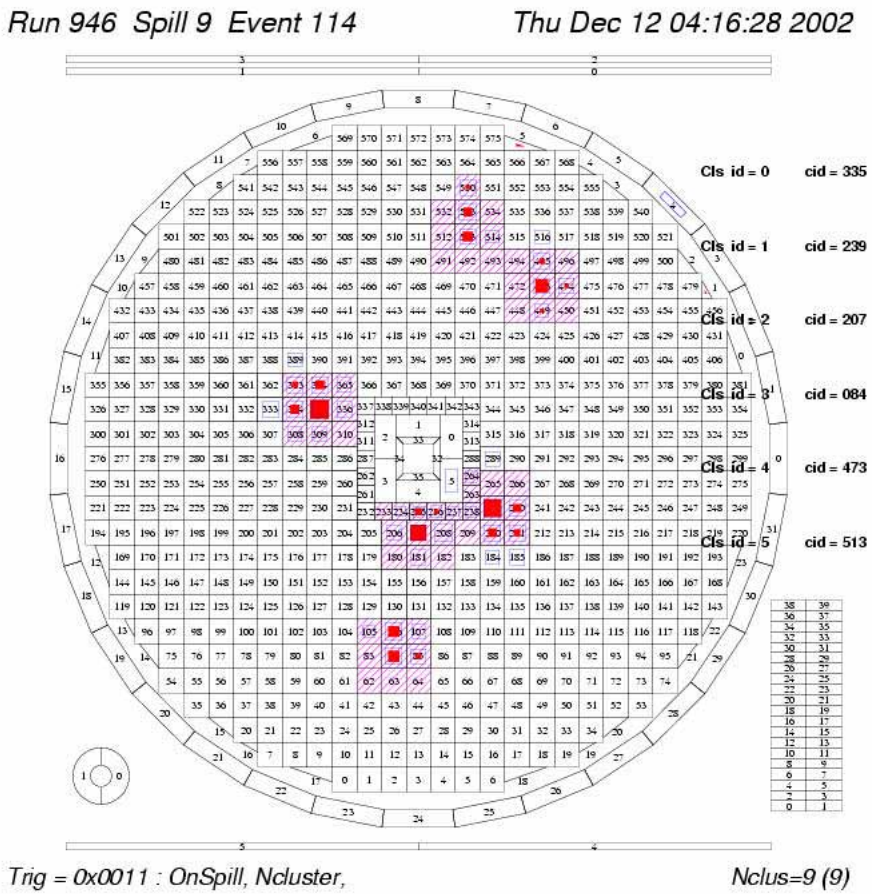
→ We can set the gain with accuracy of ±5%

→ This gain can be used as inputs for next step.



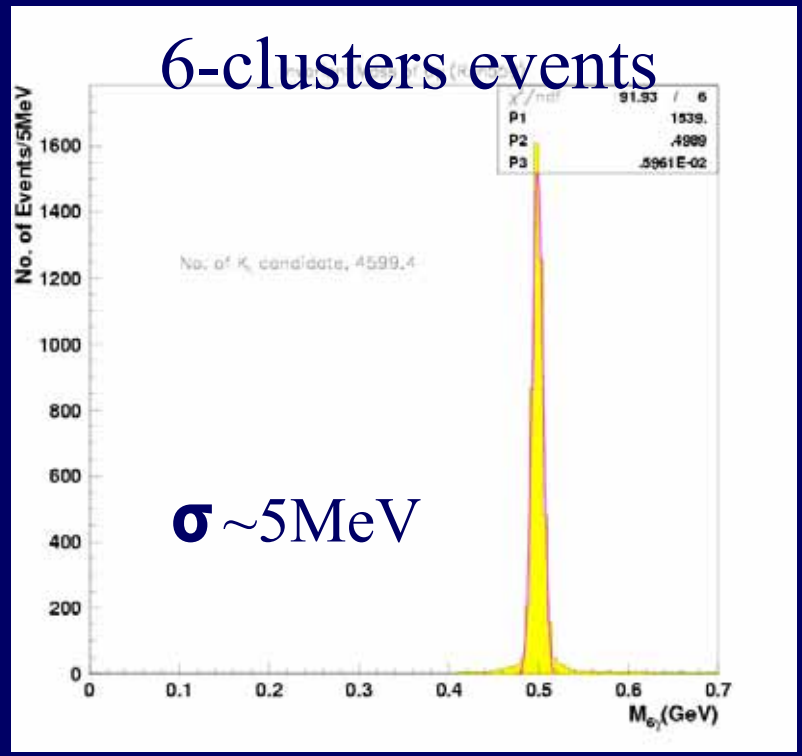


Kaon Run



$K^0_L \rightarrow \pi^0 \pi^0 \pi^0$

6-clusters events



σ ~5MeV

Detector Construction

～Barrel Part～

Detector Construction

upstream

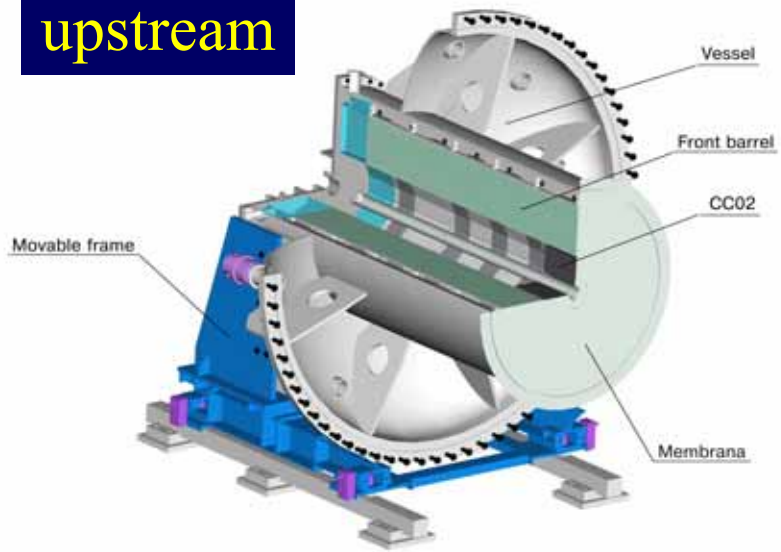
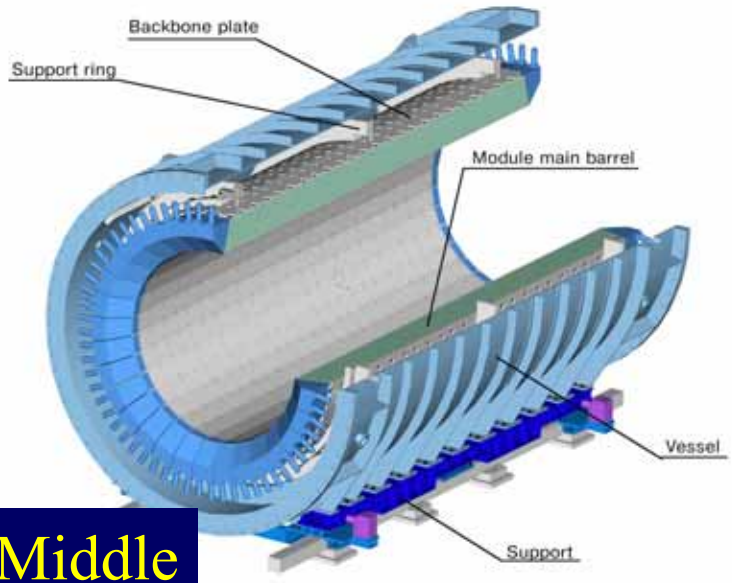


Fig.2



Middle

Fig.3

Downstream

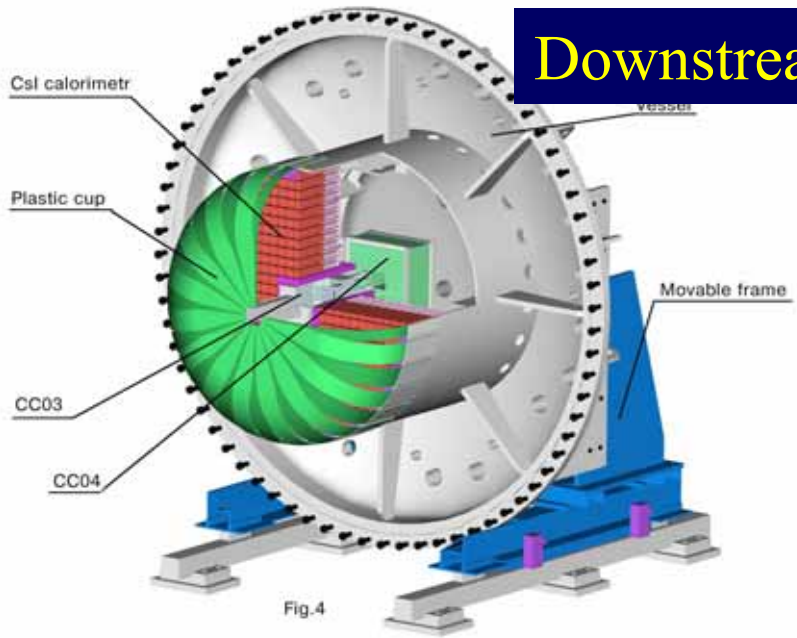
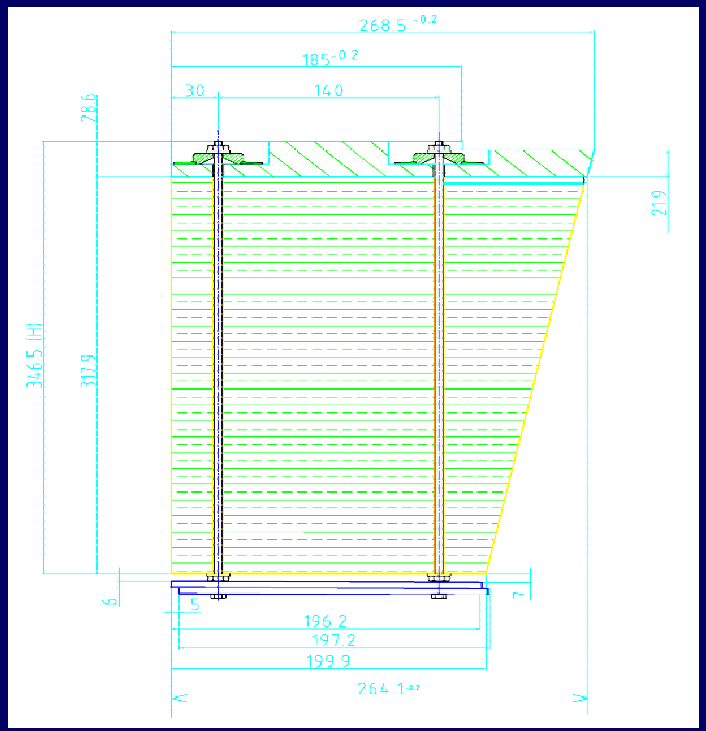
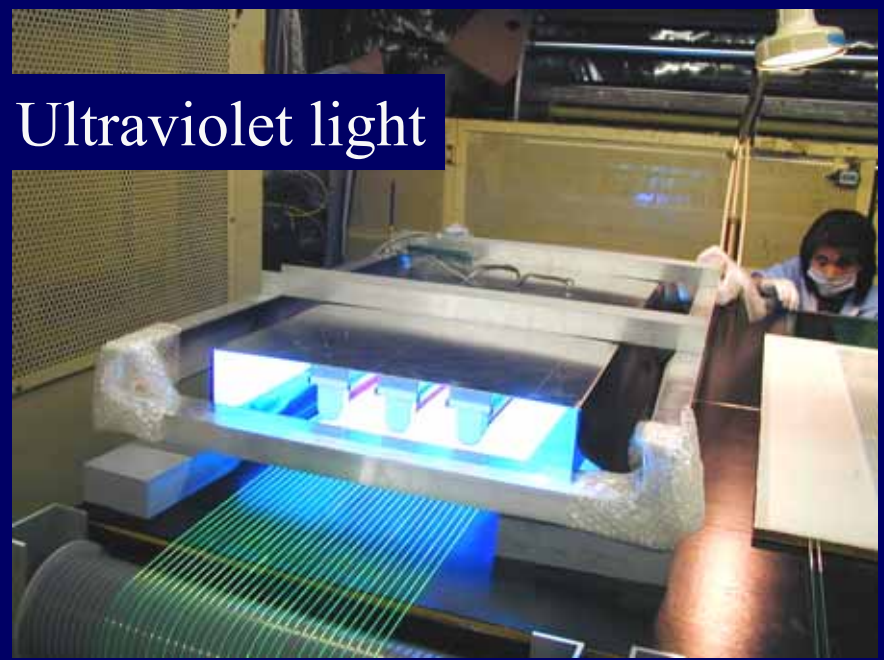


Fig.4

Barrel Fabrication





Ultraviolet light

Fabrication of Front-Barrel Modules

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

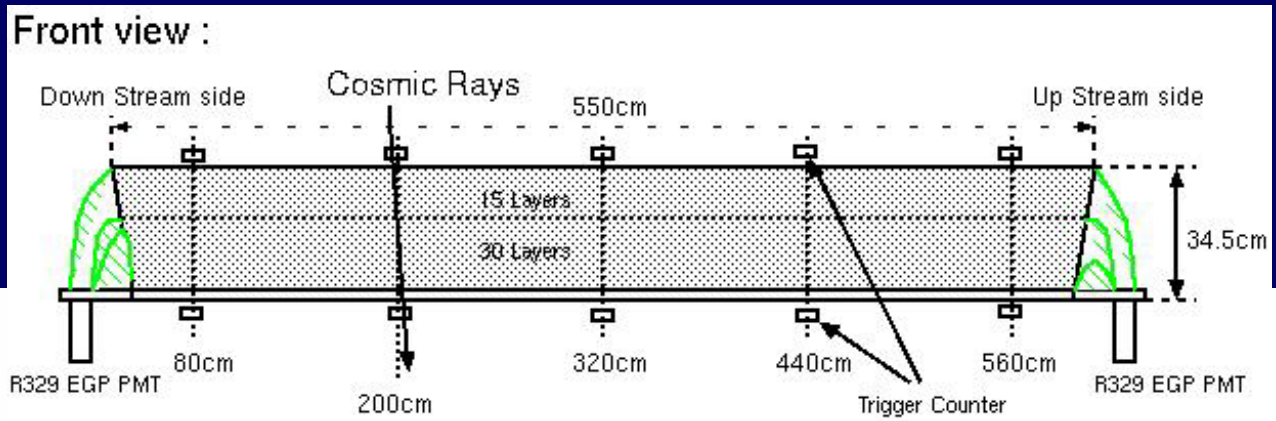
The fabrication of the Main Barrel modules : ~Sep 24, 2003.

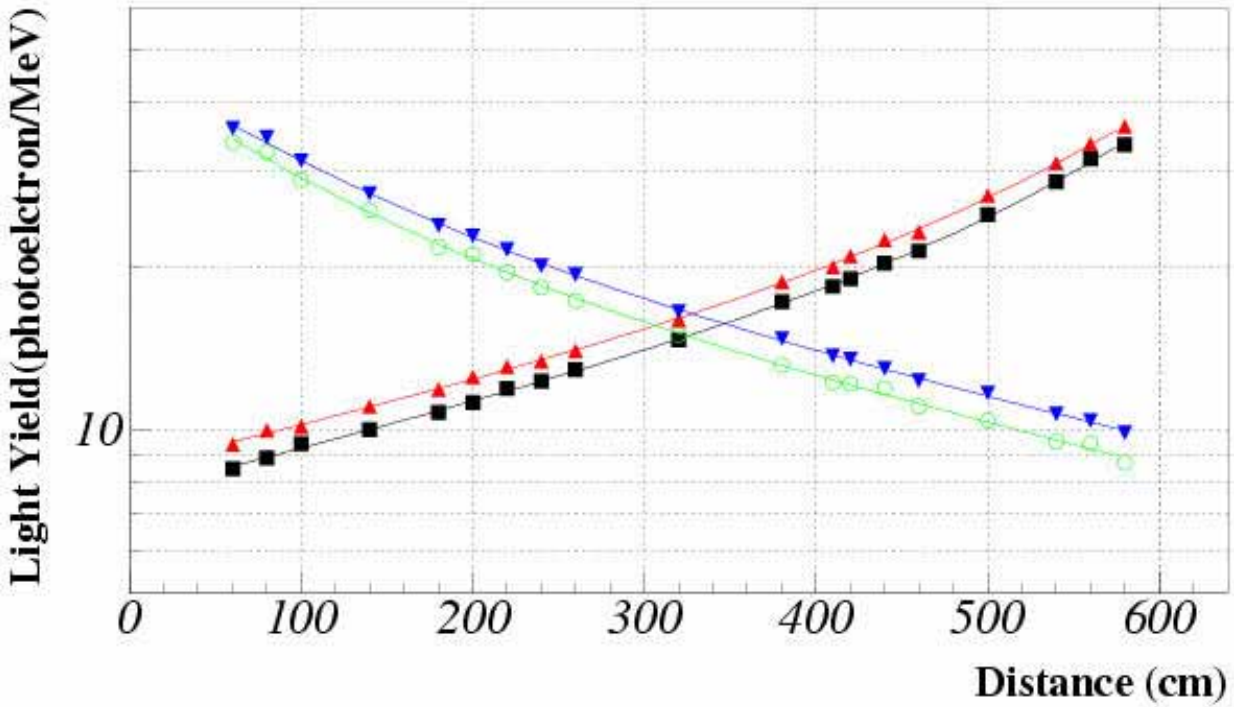
Barrel-module Fabrication

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

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

Cosmic-ray test of single barrel module





Average : ~14 photoelectrons/MeV-deposition at Center

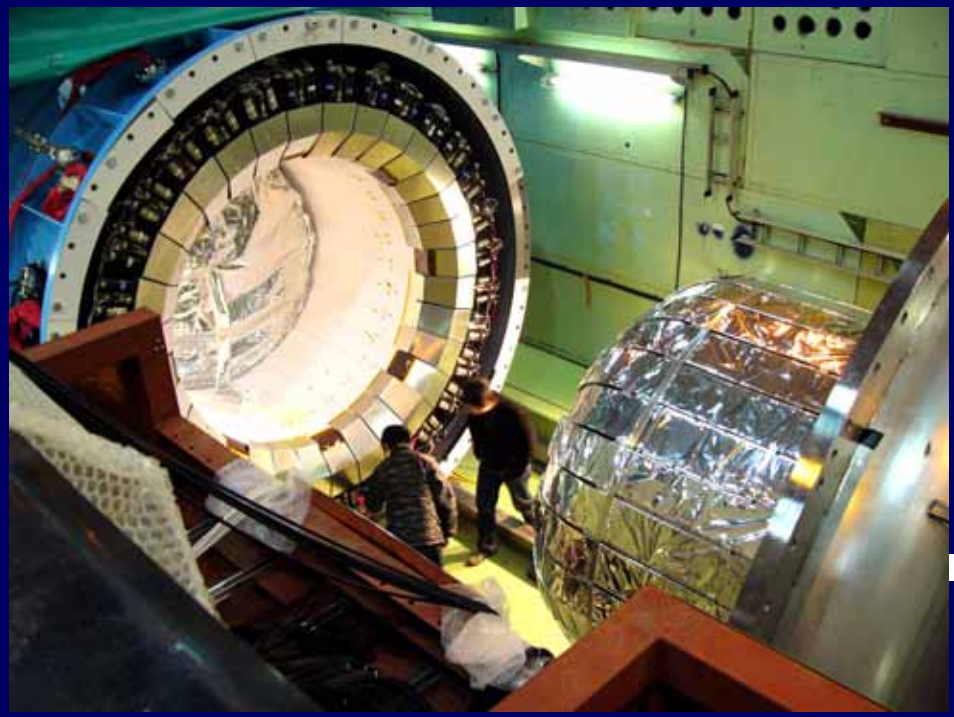
Front Barrel Assembling

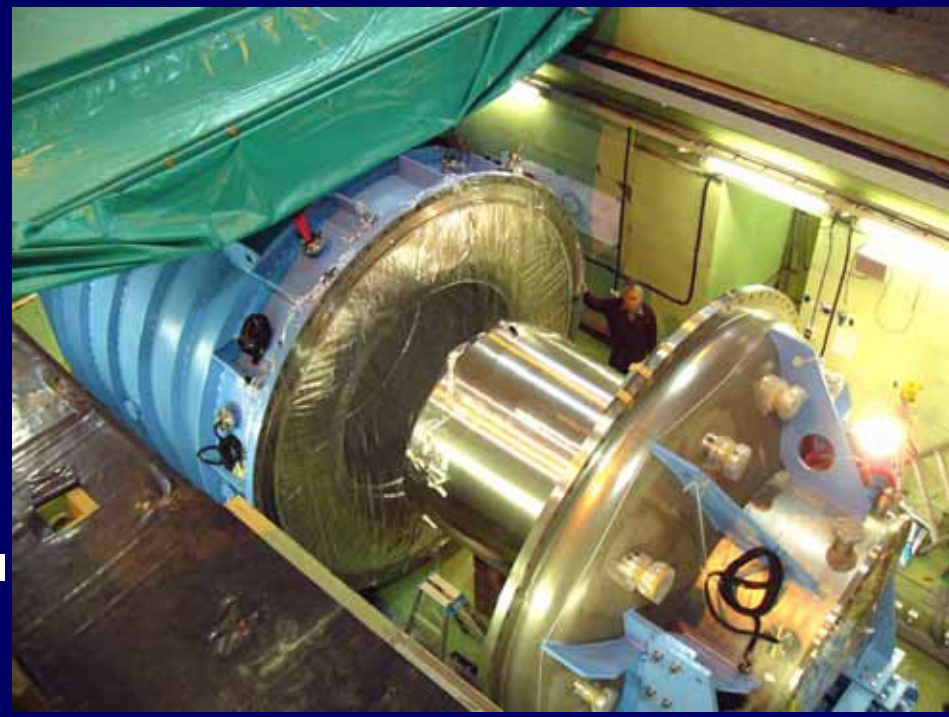
Sep. 5, 2003

Main Barrel Assembling

Dec 17, 2003

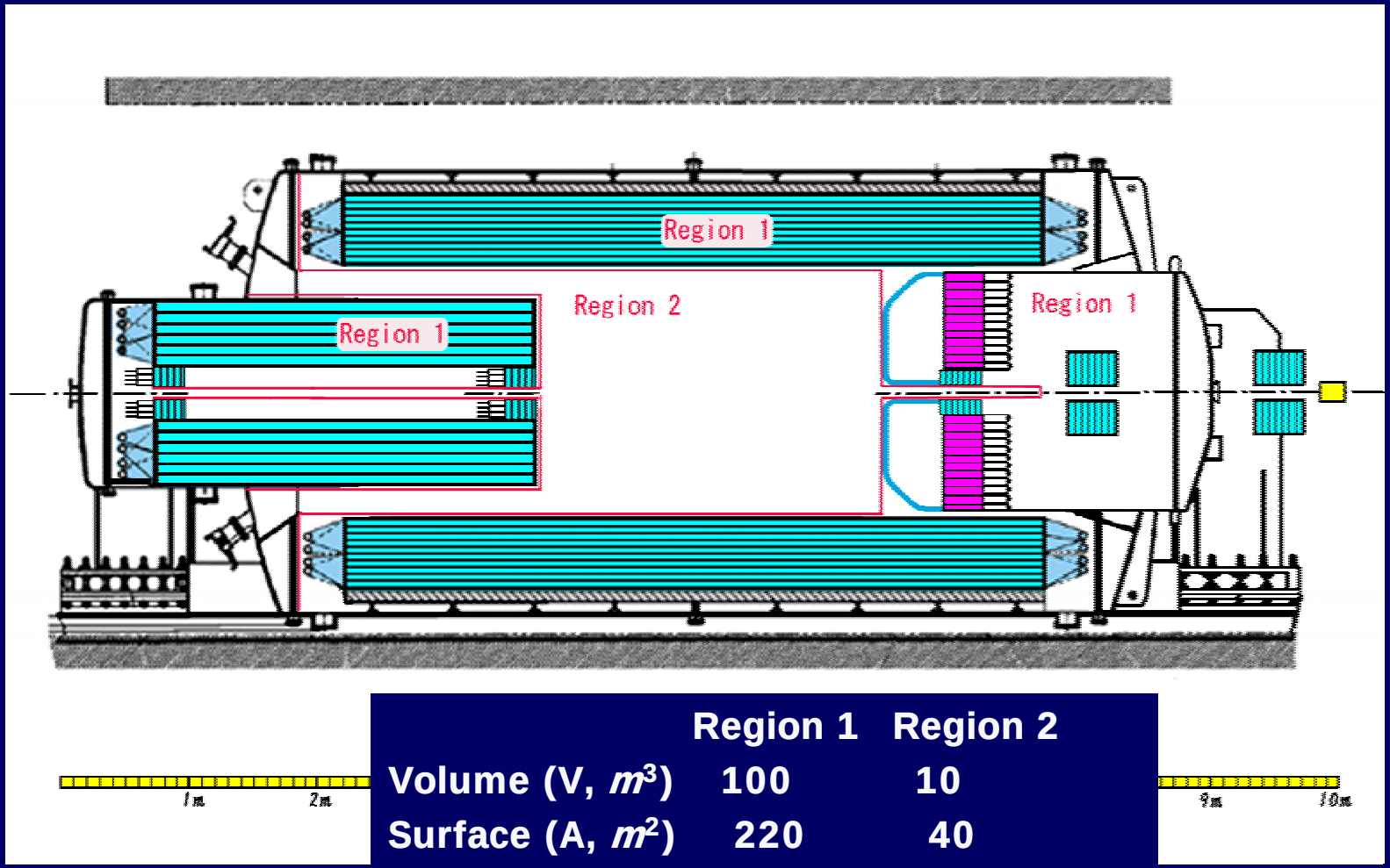
Detector Integration





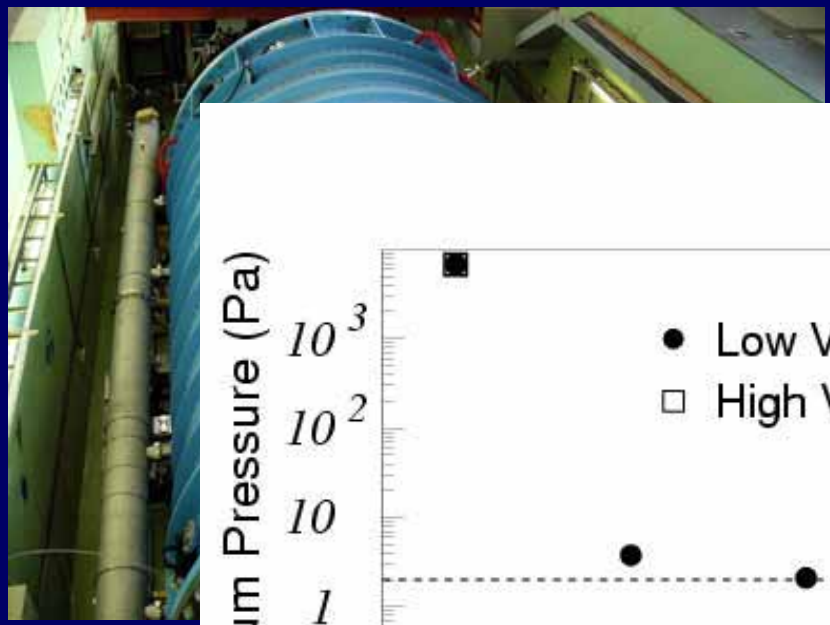
Jan 22, 2004

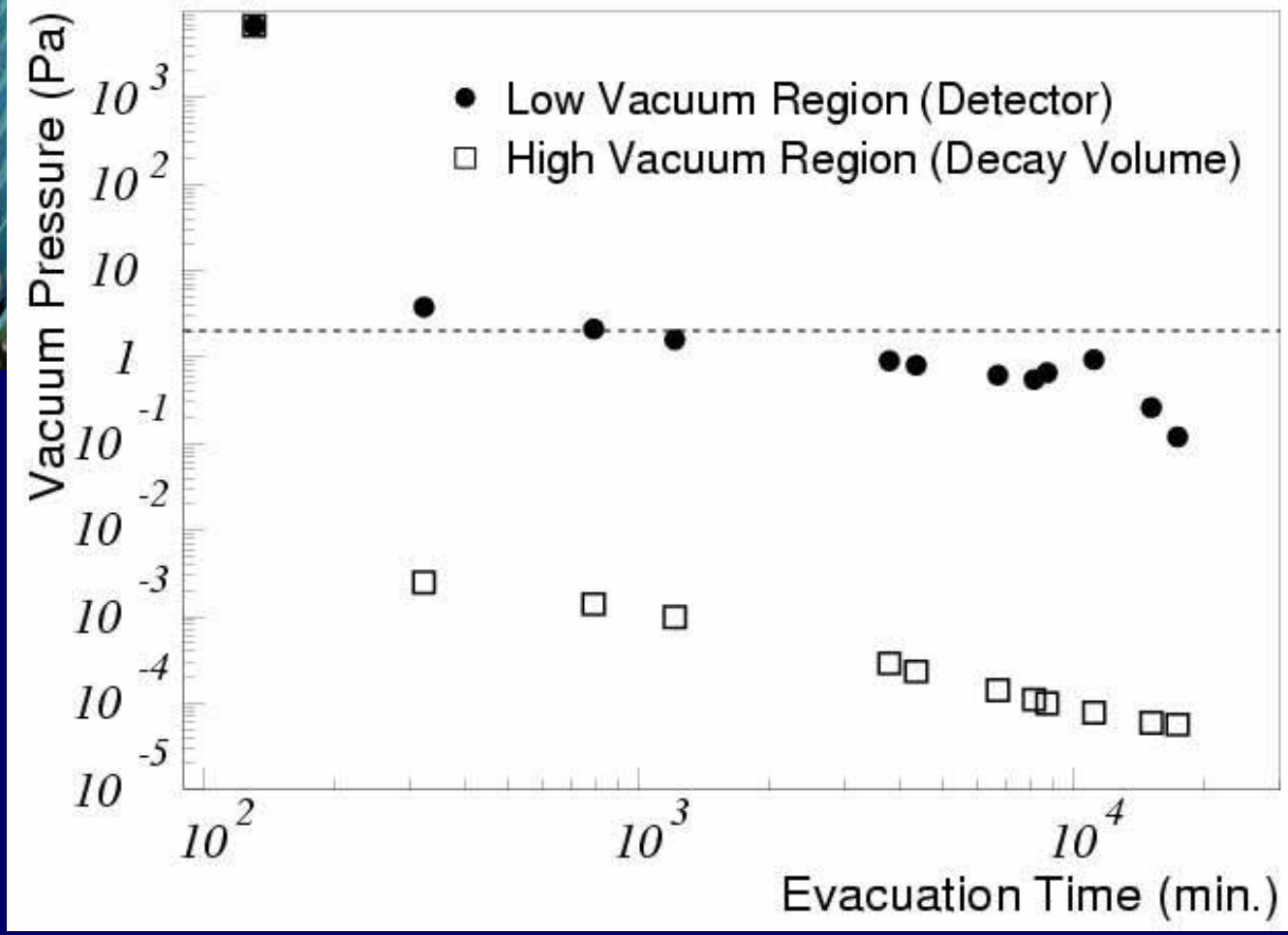
Vacuum



	Region 1	Region 2
Volume (V, m^3)	100	10
Surface (A, m^2)	220	40

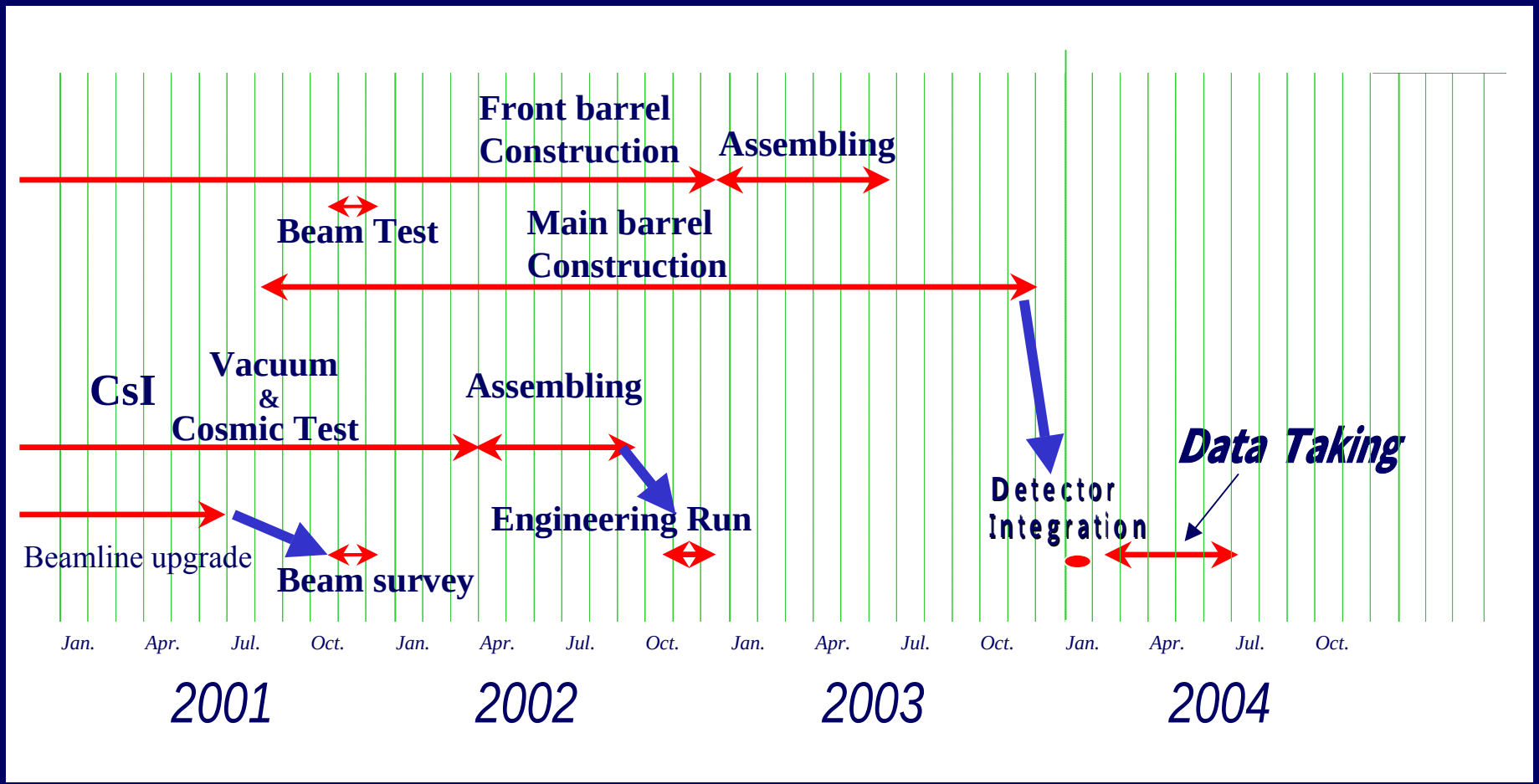
Vacuum



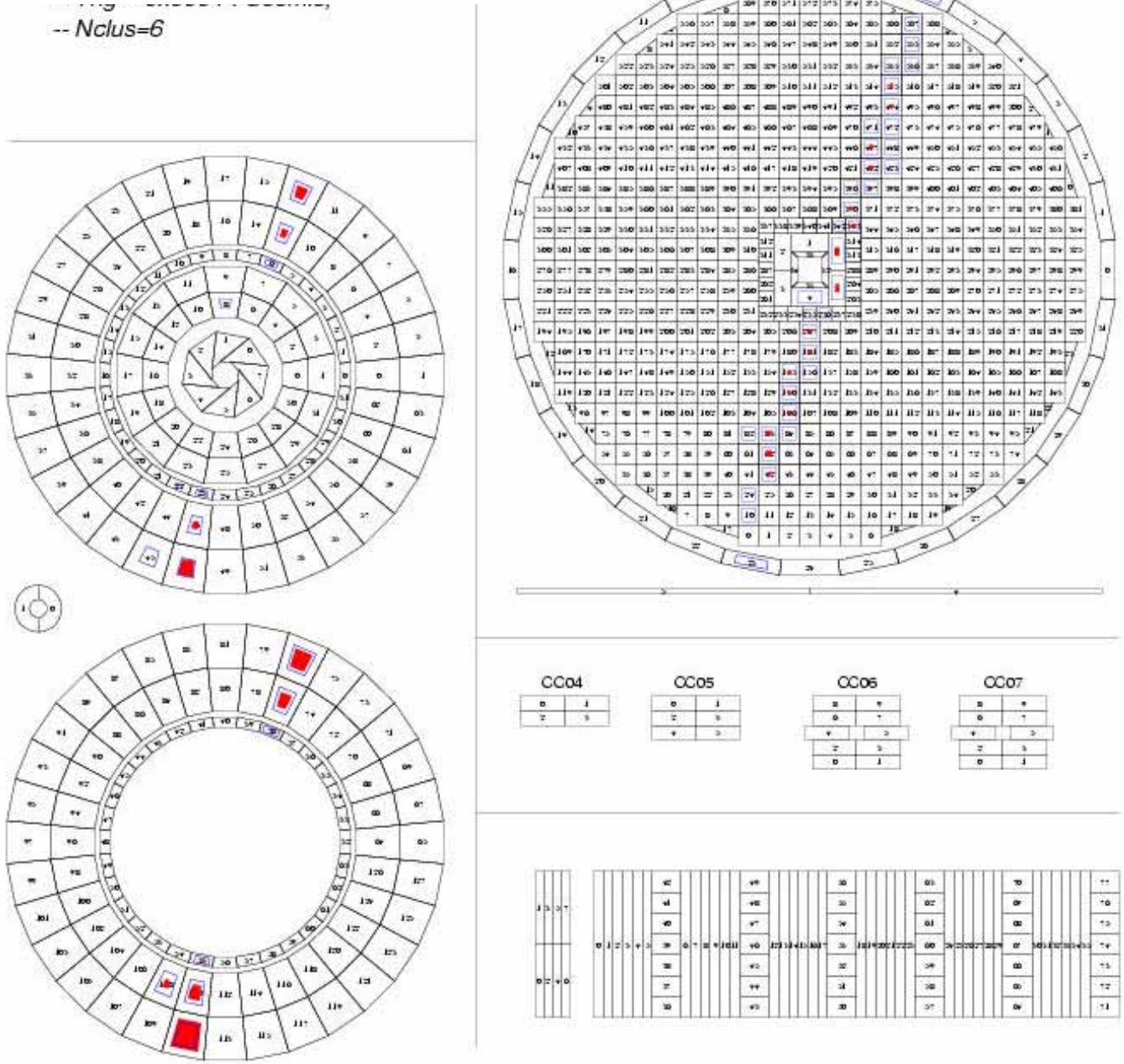

Vacuum Pressure (Pa)
10 3
10 2
10
1
10 -1
10 -2
10 -3
10 -4
10 -5
Low Vacuum Region (Detector)
High Vacuum Region (Decay Volume)
10 2
10 3
10 4
Evacuation Time (min.)

Schedule

Proposal was submitted in 1996.



Cosmic-ray test

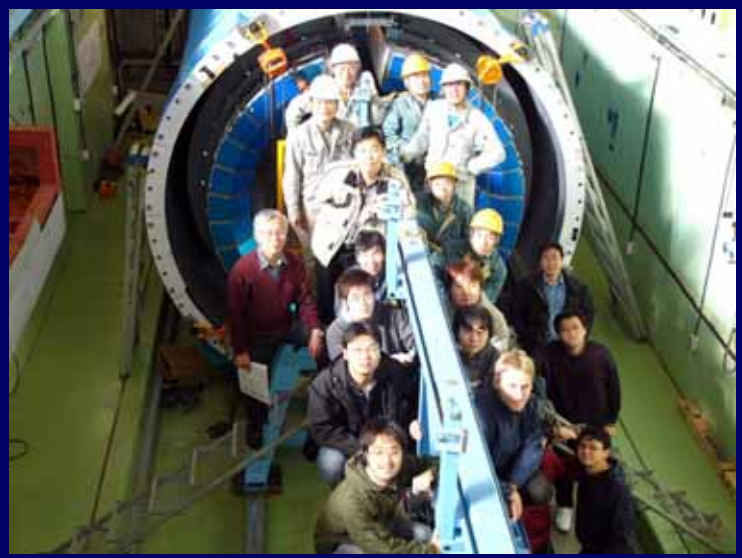


Summary for Status Report その1

✧All detector constructions and its integration were completed !!!

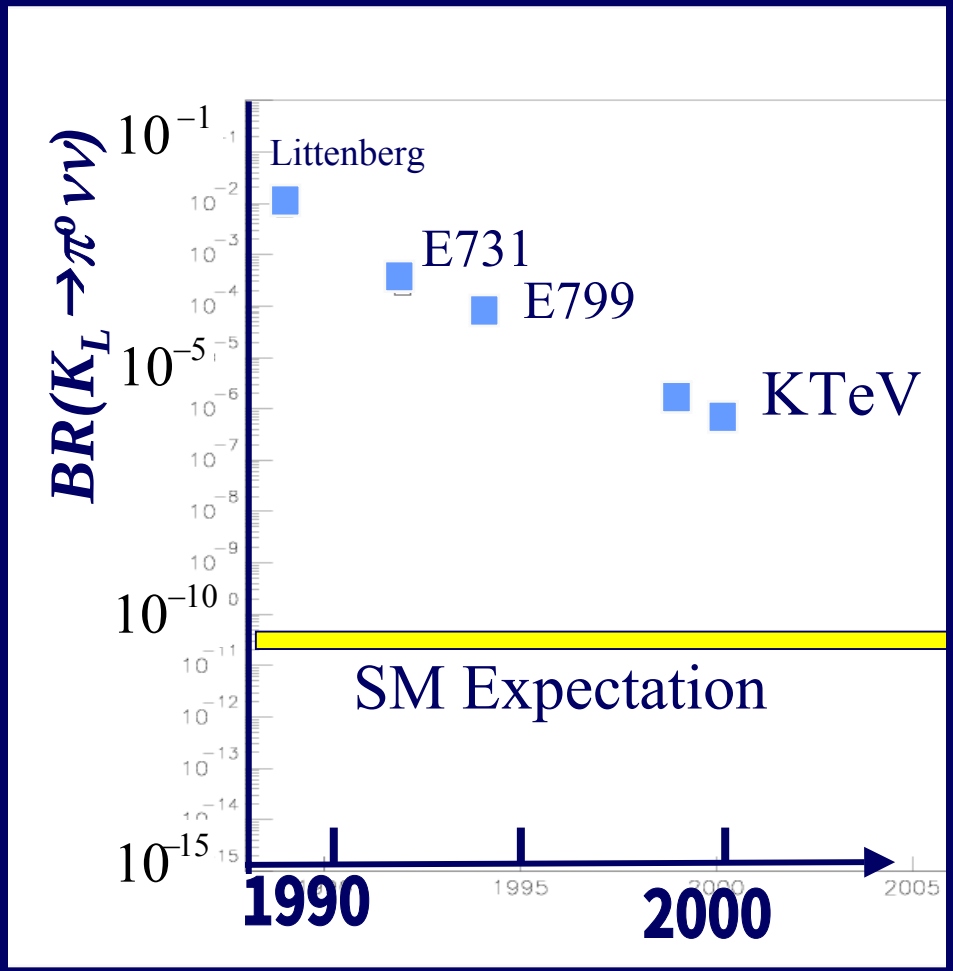
✧All system including Detectors, DAQ and Vacuum
are properly working !!!

✧First beam was delivered on Feb. 17th, 2004
→ Status Report そのII presented by Sugaya-san, Osaka-U

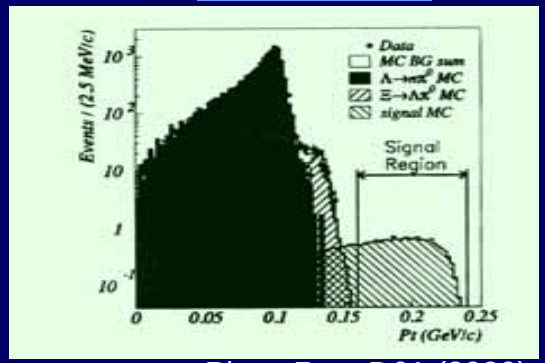


Current Experimental Limit

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

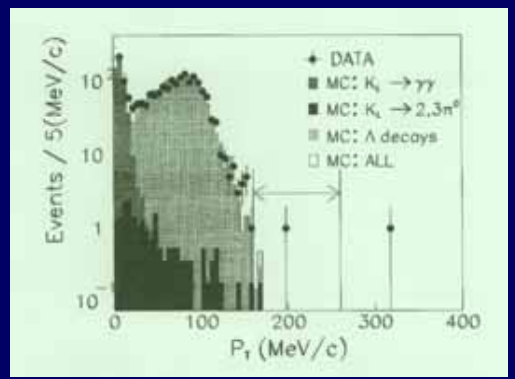


$\pi^o \to e^+e^- \gamma$



Phys. Rev. D61 (2000)

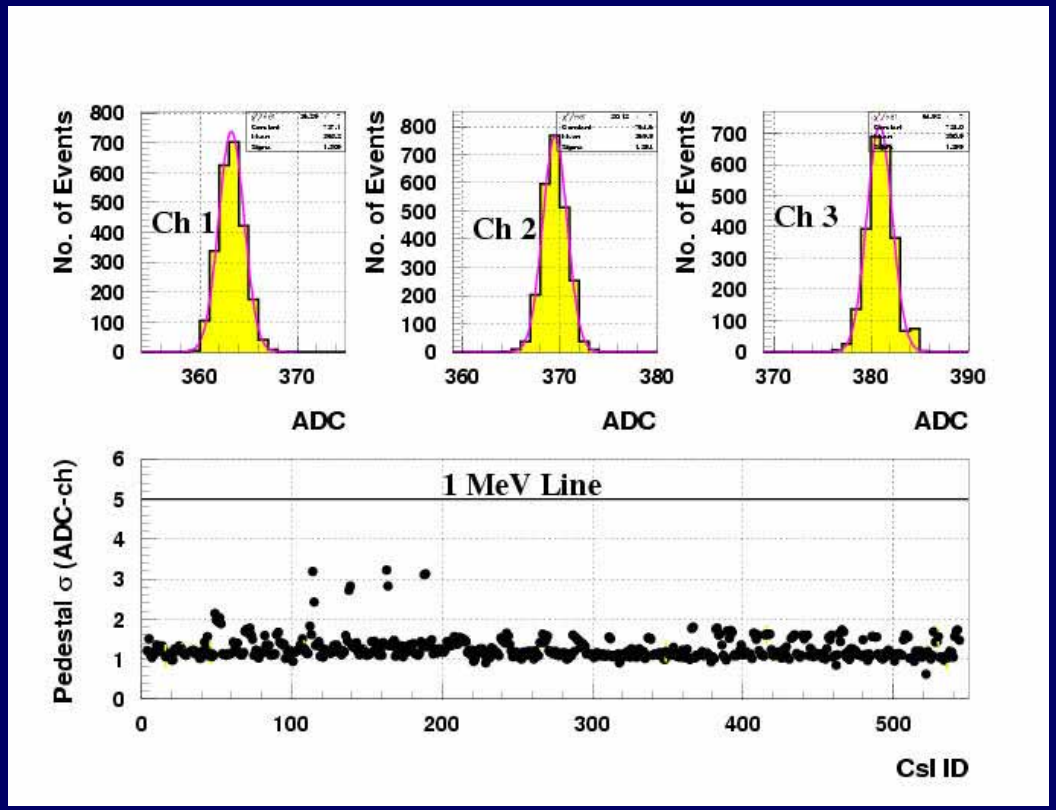
$\pi^o \to \gamma\gamma$



Phys. Lett. B447(1999)

Engineering Run electric noise

Delay cables



50 fC/ADC-ch

CP violation in the Standard Model

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

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

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

- Standard Model
  - ⇒ **CP Violation**
    - → **η**